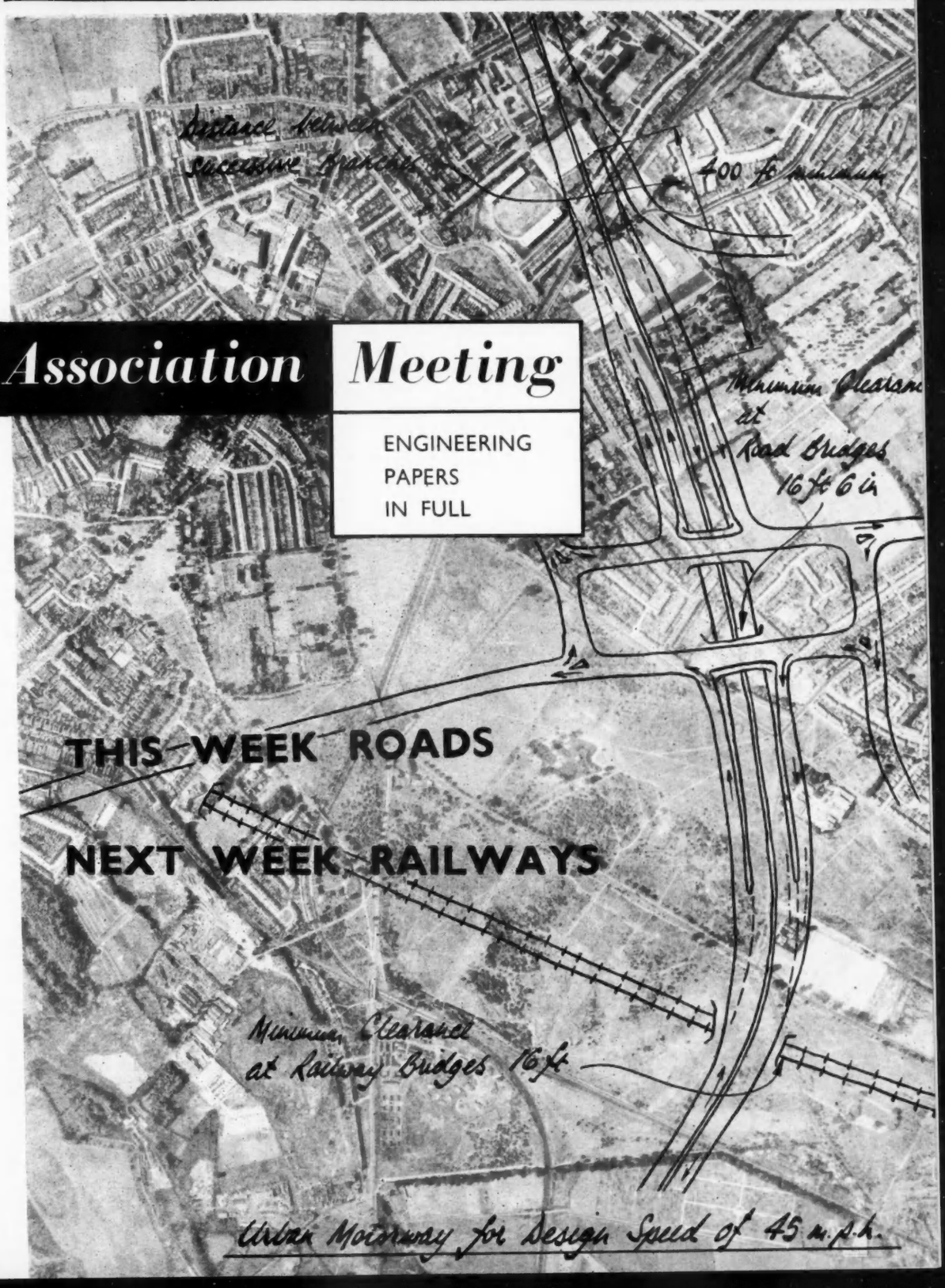
ENGINEERING

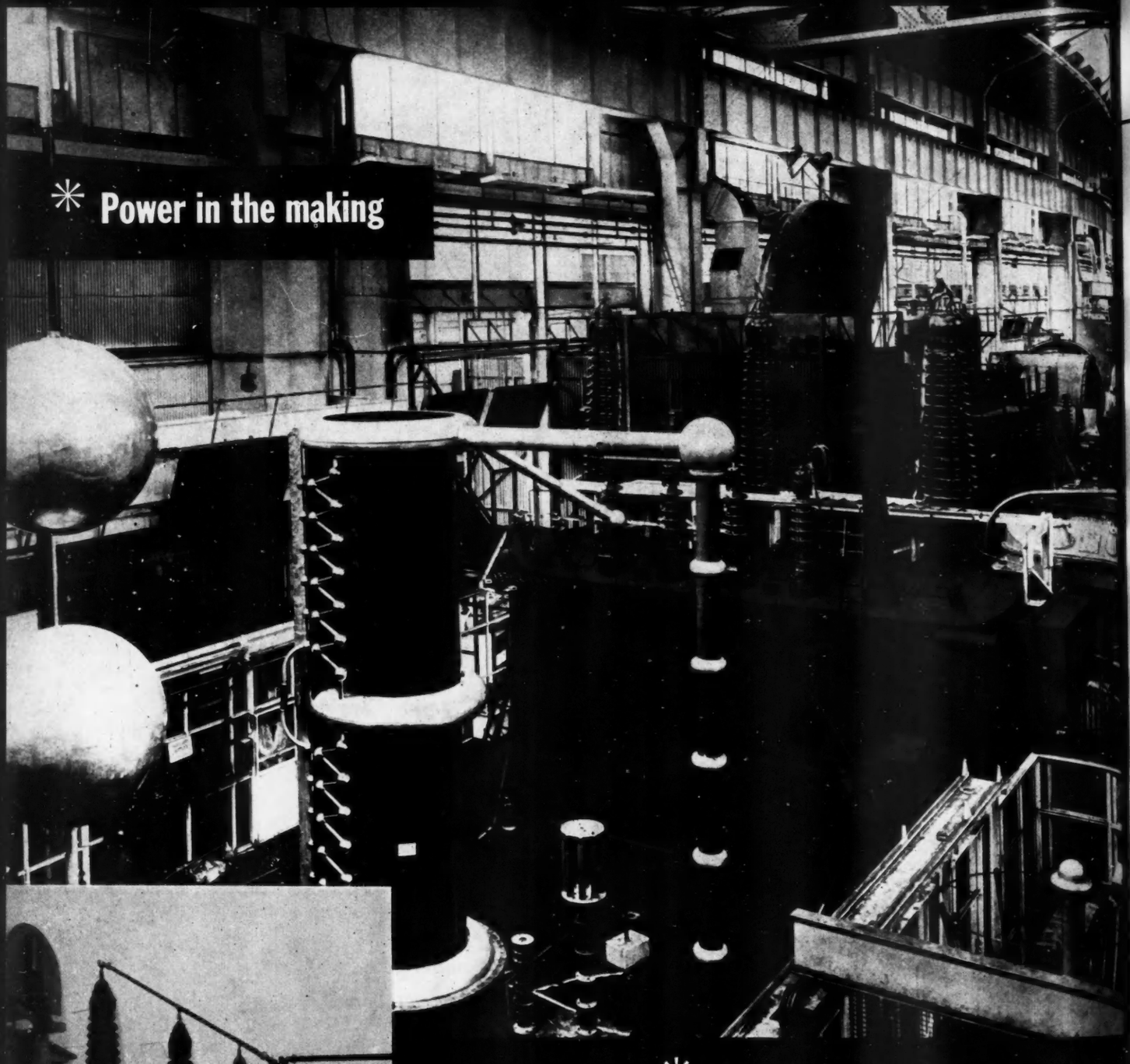
THE UNIVERSITY OF MICHIGAN
OCT 2 1959
ENGINEERING LIBRARY


Distance between successive Gantries
400 ft minimum
Minimum Clearance at Road Bridges 16 ft 6 in
THIS WEEK ROADS
NEXT WEEK RAILWAYS
Minimum Clearance at Railway Bridges 16 ft
Urban Motorway for Design Speed of 45 m.p.h.

British Association Meeting

ENGINEERING PAPERS IN FULL

Transformers



✳ Power in the making

The impulse test plant shown here with a 120 MVA transformer on test is rated at 2½ million volts at a stored energy of 60 kW secs.

The autoclave plant behind, used for vacuum drying and oil impregnating processes, is capable of fully enclosing the largest tank yet manufactured by PARSONS.

✳ Transformers have been increased in size over the years to meet the demands dictated by the growth of power systems. Always during this time PARSONS have produced the larger types of transformers. In keeping with these developments PARSONS have installed manufacturing and testing plant to produce power transformers of the highest voltages and ratings

POWER TRANSFORMERS
TURBO-GENERATORS
CONDENSING PLANT

PARSONS

C. A. PARSONS & CO. LTD.
HEATON WORKS · NEWCASTLE UPON TYNE

ENGINEERING

Vol. 188 No. 4873 11 September 1959

PUBLISHED EVERY FRIDAY

Contents

145 **Leading Article**
Interview with Ourselves

146 **Plain Words**

146 **Weekly Survey**

147 **Letters to the Editor**
Publicity Abroad
References by Code
Seaworthy Reactor

151 **Automobile Engineering**
Mercedes-Benz Latest 220 Models
Volkswagen Improvements for 1960

152 **Companies in the News**

154 **Special Article**
Escape and Return: Astronautics Conference Report

156 **Atomic Review**
Departures in Gas Cooling

165 **On the Shelf**

165 **Publications**
Grundlagen der Chemischen Technik. Vol. IV Wärmeaustauscher
Gleichgewichtsgase der Verbrennung und Vergasung.
Kesselspeisewasser
Richtlinien für die Aufbereitung von Kesselspeisewasser und Kühlwasser
Pressurised Packaging (Aerosols)

166 **New Books and Trade Publications**

174 **At Home**
Post-and-Beam Houses

175 **British Association Meeting**
Building the London-Birmingham Motorway
Critical Survey of Bridge Design
Road Improvements: Choosing Priorities by a New Formula
Promising Future of Vertical Take-Off

. . . . . .

148 **New Plant and Equipment**
Spark erosion machine, Industrial fan, Dual-role lorry, Circuit breakers, Backing-off machine, Label gumming machine, Direct buried transformer, Gas regulator, Temperature controller, Jig clamp, Fault detector, Induction furnace, Automatic welding machine

153 **The Human Element**

159 **Construction**
Frost Action Below Cold Storage Buildings
Wellington's New Airport is Within the City
Hydroelectric Project in Alberta

Weekly Construction Notes

161 **Research and Development**
Thermoelectric Power: An Investigation of its Possibilities—Part 3

167 **Design**
Aboard the Skipjack
Picture Page
Nomogram for Finding Conveyor Belt Width
Stiff Mesh in Sheet and Roll
Roller Conveyor for Argosy Aircraft

171 **Production**
Coking at the Pit Head
Pressure Vessels and Heat Exchangers
Speedier Cement Handling
Mechanical Handling at Vauxhall Motors

173 **Operation and Maintenance**
Modernising a Small Factory
No Port Facilities

173 **Marketing**

ENGINEERING *Appointments Section faces page 160*

Interview with Ourselves

THE most persistent television interviewer would think twice before waylaying a runner in the course of a race. But if the runner were one of many engaged in an endless relay race, the interviewer would be justified in questioning one of them. In the race of science and engineering, in which we are all relay runners, we must often wonder where and when, if ever, the race will end. We have not marked out the course, for the simple reason that we have no idea where we can go until we actually go. We run because we must. We know there is no simple answer to the question what is the ultimate objective?—so we seldom frame the question. And interviewers seem to think it would be rather crude to ask us; it would imply a certain doubt or scepticism in the mind of the questioner, and that would be unforgiveable in this age of acceleration without brakes.

If the question is unanswerable, and no one wants to put it to us, why should we ask it? Why should we interview ourselves? The traditional answer for science is that science—the pursuit of knowledge—is worth pursuing for its own sake. But that reason has worn thin. It was adequate in the early years of the Royal Society, and it is still trotted out today, but even if we leave armaments out of the argument, science and engineering are augmenting the natural power within us at such a rate that it is now quite clear that we have acquired an appetite which must be continually fed. We indulge in science because our thirst is unquenchable. And now it is the same with engineering: a new development of a prosaic machine has to satisfy the searching scrutiny of accountants as well as engineers before it is sanctioned; but a possible development of a rather wild idea receives State support at the highest possible level provided it seems to represent the vanguard of engineering in the coming decades. We cannot bear to think that someone else may beat us to it, so we run as fast as our economic legs will carry us.

It is difficult to test the reasonableness of this race by the traditions and teachings of a Christian society, because the message of the New Testament has always been personal and directed to the individual, whereas modern science and engineering are the products of corporate thinking and activity. A lone inventor of weapons is rather odd, if not frightening, but a whole government department devoted to the organisation of weapon design and production is outside the orbit of moral judgment. No one would question, then, the right of a company to develop advanced computers; in fact, we think they are doing a splendid job for society.

The new factor in our condition is this sudden—historically speaking—facility to harness a whole team of brains in such a way that the team is greater than the sum of the parts. We have acquired powers which transcend the power of the individual, and naturally we want to use them even if we can only dimly see where they will lead us. We know more about the means than we do about the end. The political answer is that we are raising our living standards but that is not an answer which gives much satisfaction.

There is one other factor in our condition which is fundamentally new. It is that now each fresh generation of scientists and engineers is not required to tread the same path of knowledge and understanding which over the years has led to contemporary practice. Indeed they would not have time to do so, but must accept many things as accomplished facts which there is no time to inquire into. A university degree course is a sophisticated method of enabling the future engineer or scientist to jump on to the moving train of thought which we are all helping to propel, and in due course his contribution will help to propel it faster. To the uncertainty of not knowing where we are going, we are thus adding the mystery of not knowing how we have reached the present stage. Small wonder that mankind is frightened, as Sir James Gray said in his address to the British Association.

In times of prosperity, as now, there is little inclination to ask such awkward questions. When everything is going so swimmingly, how can there possibly be any sort of basic maladjustment? Yet there are men, like Sir James Gray, who feel compelled to ask them. He looks to the biological sciences for the answers, but however much these sciences develop in the future they are not likely to give the solution to the one fundamental question which we have posed. The fact is that we have become over-confident in our own abilities. It is strange that belief in our own power to perform the miraculous has coincided with a decline in belief in the divine power to perform miracles. In our state of uncertainty about ultimate objectives, it might be far better, and more productive, to acknowledge the power within us as something given to us, not generated by our own superior intellects. That way, we may glimpse the absolute frame of reference, and thus make sense of ourselves and our works.

Cover Picture.—*Britain's transport problems, examined at this year's British Association meeting, centre at present on the question of road development. Our cover shows a figurative Gordian knot of tangled suburban streets and overcrowding, on which is superimposed the road planner's bold stroke of rationalisation.*

Plain Words

I have discovered the secret of success. To reach the highest places in business or public service requires a combination of qualified ignorance and persistent curiosity. Unfortunately, they are qualities rarely found together, since a tendency to ask questions leads almost inevitably to the rout of ignorance, and it is for this reason that comparatively few succeed in climbing to the top. The problem remains: how can one put this tempting but tantalising revelation into practice?

The idea came to me as I read yet another partisan complaint about the misanthropic attitude of the authorities to the supposed administrative aspirations of scientists and engineers. A capable engineer, one gathers, has about as much chance of promotion as an efficient batman, whose virtues are cherished secretly by the officer he serves. " Scientists need not apply " was the title of the article in question. " Is it really the case," the indignant writer asks, " that an Atomic Energy Authority which includes such persons and personalities as Sir William Cook, Sir William Penney, Sir William Owen among the full-time members of its Board and a number of other eminent scientists and engineers among the part-time members, cannot find one among them able and fitted to be the leader of the Board as its Chairman?" But with all those Bills to pay, it's not surprising that a man was chosen likely to prove acceptable to the Treasury.

Private companies are just as bad, according to the experts. Only three years ago—or was it four—a paper delivered to a British Association meeting demonstrated that engineers rarely found seats upon the boards of engineering companies. But there may be method in this exclusion of the specialist. A shameless and determined novice is often better qualified to ferret out the truth than a busy expert with his vast accumulation of habitual assumptions.

On one side we have those who murmer that, for want of qualifications, their talents and abilities go unrecognised; and on the other, those who find their qualifications a stumbling block to their ambitions.

Fools! Fools, all of them! The answer is simple. If to succeed in engineering one must be an accountant or economist, then to succeed in banking one must be an engineer. Already engineers are rising in the hierarchy of the World Bank. Engineers figure prominently in the pantheon of literature, music, art and architecture. They provide the flower of the legal and medical professions. They have all marched upwards to the top. While we poor plodders, like the brave old Duke of York, are neither up nor down.

CAPRICORN

Weekly Survey

Who Will Finance Exports?

The ability to lend huge sums at low interest rates over a long period is rapidly becoming an essential condition of successful exporting where capital goods are concerned. The makers of plant and heavy machinery in particular, which represent a considerable capital outlay, are worried lest they should be unable to compete at all without Government support. One of them, Mr. M. A. Fiennes, managing director of Davy-United Limited (who are the country's largest makers of capital plant for steelworks), wrote in a letter to *The Times* (28 September) complaining of the " inadequate facilities for credit and insurance " available to companies concerned in the export of capital goods. He wrote in support of Sir James Reid Young, chairman of International Combustion (Holdings) Limited, who put forward the view in the same columns two days earlier that unless the Government, industry and the banks " pool both their brains and their resources " to devise a system of development loans for important capital goods projects abroad, " Britain's capital goods exporters are probably heading for a quite unnecessary recession."

Mr. Fiennes refers to Britain's adherence to the Berne Union, whose members support the five-year limit for credit insurance and gives an example of 10 years' credit being granted to buyers of steelworks equipment by members of the union, allegedly with the support of their national banks. " Either we should call the offending members to book," states Mr. Fiennes, " or we should resign from the club."

The factors in the underwriting of British exports of capital goods are too numerous and complex to analyse in a short note. Other letters to *The Times* pointed out the tendency of some governments " to pay for their purchases by the sale of their own products rather than by obtaining long-term credit " (Mr. P. Adam, managing director of Adam and Harvey Limited, and the strong bargaining position of countries with the resources to provide long-term loans (Mr. A. G. Ellinger). British industry is decreasingly privileged in that sense because the country as a whole does not provide any exportable savings balance. In other words, we eat too much to finance steel mills in India till their operators get the money back from operating profits.

Nonetheless, it is true that long-term credit is becoming a weapon in the international competition for world capital goods markets now developing, and equally true that Britain cannot afford to stay out of the race. The Radcliffe Committee were aware of this possible weakness and indicated that there may be a " gap in the capital market for the finance of overseas credit running from between eight and twelve years, but indicate that a Government sponsored export finance corporation should only be necessary if existing financial institutions cannot make the necessary finance available." It would be useful if the capital goods industry could demonstrate the existence of this gap and suggest how it might be closed.

Redeploying Men and Machinery

In the postwar years a large measure of success has been achieved in preventing widespread unemployment. Nevertheless, in certain areas serious pockets of unemployment have developed and are likely to continue to do so as some of the older industries sink in the wake of technical progress. While this situation is met to some extent by migration of labour to areas where new industries are expanding, it is by no means desirable that this should be the only solution to the problem.

The Distribution of Industry (Industrial Finance) Act 1958 permits the Treasury to give assistance on the recommendation of the Development Areas Treasury Advisory Committee to any undertaking which is likely to reduce unemployment in a place of high and persistent unemployment. In the first eleven months after the passing of the Act only £1·14 million had been advanced under schemes expected to provide 2,606 new jobs.

Figures released by the Treasury at the end of August, however, show that there has been much more rapid progress during the last two months. In the full 13 months assistance valued at over £5 million has been offered to 83 undertakings and is expected to result in the creation of 5,370 new jobs. Of the total, Wales is to receive £3·3 million, with the creation of 1,029 new jobs; England £0·9 million and 2,058 new jobs and Scotland £0·8 million and 2,283 new jobs.

Selling Little Cars to America

The boom in motor car production is by no means confined to this country. *Barclays Bank Review* for August notes that last year European production reached the record total of 4½ million vehicles and there is every indication that this year output will be even higher. Prospects for expansion of sales in the principal European markets are certainly good. One of the main uncertainties is the trend in exports of European cars to the United States.

US imports of European vehicles have risen from 107,000 in 1956 to 260,000 in 1957 and 432,000 in 1958. The three major American companies have also been losing ground to independent producers but are now reported to have completed preparations for the production of a new range of smaller cars which they hope will enable them to capture the whole of the expected 10 per cent rise in US sales next year. The Ford Falcon, the first of these economy cars, was " unveiled " on 2 September by means of closed circuit television at a news conference held simultaneously in 21 cities. It is a 6-cylinder 6-passenger vehicle weighing 2,366 lb or three-quarters of a ton less than the standard American Ford car. It is said to resemble the German Ford Taunus, and while the price will not be announced until next month, it is expected to be at least $200 less than that of comparable cars imported from Britain or Germany. Mr. Henry Ford expects that total sales of the Ford, General Motors and Chrysler economy cars this year will lie between 750,000 and 1 million. It remains to be seen to what extent these sales, if achieved, will be at the expense of imported European cars.

Transport Technicalities

London Transport in 1958, the annual review of the London Transport Executive, brings out the very marked effect of the seven week bus strike in May and June, 1958. While traffic carried by the underground railways showed little change compared with the previous year, total passenger miles on all types of buses fell by 22 per cent. The actual loss of traffic in the strike would have been about 13 per cent and it is clear, therefore, that there has been a considerable permanent fall in the demand for bus transport. By contrast, peak hour congestion on certain underground lines has worsened and the review stresses that if work is not begun soon on the proposed Victoria line tube from Victoria to Walthamstow, conditions on certain existing lines will become intolerable. They claim that the the new line could be open to traffic within

6 years, would cost about the same as an urban motorway of similar length but would have several times greater passenger carrying capacity.

An important factor in preventing further loss of traffic from the buses is to ensure regularity of services, particularly in cases where the time interval between buses has been increased due to cuts in the service. Since the end of 1957 trials have been in progress with prototype equipment of the bus electronic scanning indicator. Eight fully operational check points are now in use, on route 74, which transmit information to the central control point, temporarily established at 55 Broadway. If the results of the present tests are favourable other central routes are to be similarly equipped.

New maintenance procedures introduced towards the end of the year have contributed to savings in vehicles and staff. The " major dock" formerly given to every bus every 27 weeks, which involved taking the bus out of service for a whole day, has been abolished, as also has the " secondary dock " which used to be given every 9 weeks. The present maintenance procedure is based on a three-weekly inspection which takes only a few hours.

Stockholm Session for Seven

Maintaining the pace which has characterised the trade discussions of the Outer Seven Western European countries the detailed labour of treaty drafting has begun in Stockholm. This work may well go on until the end of October and a meeting of Ministers is likely in the Swedish capital in early November.

Three recent publications have noted the surprisingly rapid progress achieved. *Barclays Bank Review* for August, 1959, points out that one of the crucial difficulties to be overcome was the position of Denmark. This problem was resolved by negotiations between Denmark and Germany followed by the Anglo-Danish agreement under which, if the Free Trade Association is formed, British tariffs on Danish bacon and certain types of cheese will be eliminated and these concessions will not be nullified by increased Exchequer subsidies to British agriculture.

The London Chamber of Commerce in a booklet entitled *The Seven* reaches the conclusion that the formation of the FTA represented the best course for the United Kingdom once the European Free Trade Area negotiations had broken down. The authors are, however, less confident as to whether the formation of the FTA is likely to lead to a wider agreement with the Common Market countries. The FTA should, however, provide the answers to some of the objections which contributed to the breakdown of the former negotiations, for example, those relating to determination of origin of goods.

The European Free Trade Association, by Miriam Camps, published by Political and Economic Planning, concludes that the Free Trade Association plan is designed to make an accommodation with the six technically easy and yet at the same time preserve the bargaining position of the seven. It sees little in the plan itself, however, that is likely to alter the views of the critical country, France, and considers that the plan is a way of buying time and perhaps of strengthening the eventual bargaining power of the seven by creating some discrimination which can later be given away.

Both Barclays Bank and the London Chamber of Commerce stress the need to emphasise the constructive rather than the defensive aspects of the FTA. While some industrial and agricultural interests in the UK (including the watch and clock and paper and board industries as well as pig producers and bacon curers) may be adversely affected and can hardly be blamed for putting forward their objections, many branches of the engineering industry may well benefit from preferential treatment as compared with Germany in the markets offered by fellow members of the FTA.

Journal in the House

It is not every association whose tenth anniversary celebrations are attended by a Royal guest. The Duke of Edinburgh, who has made his interest in industrial relations well known, is to be the guest of honour of the British Association of Industrial Editors in November at a lunch celebrating their ten years of rapidly growing life.

Some idea of the importance attached by industry to its own newspapers, the house journals, is given by the £10½ million spent annually on the 1,500 such publications appearing in Britain. Set against average production costs of 2*s* 1*d* a copy for almost three hundred journals surveyed by BAIE, the fact that two-thirds of them were issued free, and four-fifths of the rest sold for 6*d* or less, speaks up strongly for the value placed upon the way in which their double function is carried out. For company magazines face in two directions; inwardly serving an industrial relations task in keeping personnel informed, outwardly spreading news of the firm and its people beyond its borders.

From the BAIE survey it appears that of the publications they examined, two out of three were internally oriented and of the remaining papers rather less than half could be called external and the rest internal and external. An eighth of the circulation analysed went overseas and, not surprisingly, the proportion of journals of the external persuasion was up to almost half.

Standards differ, from the magazine that is carried off home to the family down to the journal that goes straight into a drawer and stays there. Four plainly at the top are the British award winners at the 1959 publications contest of the International Council of Industrial Editors, announced at the ICIE conference, Milwaukee, Wisconsin, USA. *BP Progress*, published by Shell-Mex and BP Limited (editor J. Maxwell Boyd) won the first ward in the external magazine class. *The Stork*, published by Van Den Berghs and Jurgens Limited (editor, Richard L. Wilson), gained an award of excellence in the internal magazine class. *Wimpey News*, published by George Wimpey and Company Limited (editor, Charles Mann), won a certificate of merit for a publication aimed both at employee and external audience. The editorial board of *Safety*, produced and designed by Contact Publications Limited for the British Iron and Steel Federation, were awarded a special citation.

Checking up on Dutch Industry

A survey is being made in Holland of the commercial and organisational structure of companies in the engineering industry. The investigation will cover investment policies, the division between exports and domestic sales and fiscal matters. It is being carried out by the Engineering Employers' Society and is expected to take at least 18 months.

The investigation has become crossed to some extent with the activities of the secretariat of the European Economic Commission in Brussels. The EEC has begun an investigation into administrative regulations in the six member countries of the European Common Market since these regulations have the effect, and have often been designed to have the effect, of hampering trade.

It is not likely that the Dutch industry has been singled out for special treatment though the fact that the EEC offices are in Brussels (and the Dutch and Belgians are mutually sensitive about the motives behind trade regulations in spite of the successful operation of Benelux) may make the Dutch sensitive to the fact that they seem to have been the first on the list. They can recall too that in the early days of the ECM idea, even before the treaty of Rome was ratified, they had a large number of visitors from Western Europe inquiring into alleged dumping activities.

The art of manipulating administrative obstacles is, however, practised by other members of the European economic community and their turn to be investigated may yet come.

Letters to the Editor

PUBLICITY ABROAD

SIR, As an editor on Canada's leading metalworking magazine, and also as a British immigrant very interested in the sale of British products over here, I have observed that the British genius for understatement is causing would-be exporters to Canada to miss the boat in more ways than one.

Each day my desk is flooded with news releases, new product announcements, new publicity catalogues, brochures, and bulletins from many parts of the world. Many of them come from firms which really have far less to tell us than many British firms which apparently don't think it worth the threepenny postage to tell Canadians what they have to offer, or what they are doing. Furthermore, those British releases we do receive are so often very badly compiled, badly typed on the inevitable foolscap sheets, and accompanied by feeble illustrations.

Modesty may be a virtue in some respects but I suggest that it is no virtue on the part of people hoping to attract attention in one of the world's most fertile metalworking markets, and in a country where the fellow who shouts the loudest so often gets the business.

Yours very truly,
JAMES A. WELLER.

80 Pintail Crescent,
Don Mills, Ontario, Canada.
25 August, 1959.

REFERENCES BY CODE

SIR, The need for comprehensive lists of references is expensive of reading time and typescript. They are not the main matter of a paper or article but merely supporting information to which, I am sure, relatively few people refer.

Could we not adopt a coded system, perhaps derived from the Universal Decimal Classification, so that each technical journal in the *World List* had a discrete code number and the volume and page numbers appeared as secondary ciphers. A reference to Vol. 10, p. 102 of ENGINEERING might be 6211.10.102. (A four figure or higher number code is suggested to make a clear distinction from books and pamphlets, which usually commence with three ciphers.)

Lists would be shorter and when all branches of industry computerise data, it would facilitate a computer search for information.

Yours truly,
J. C. B. WILLIAMS.

44 Birdwood Avenue,
Maidenhead,
Berkshire.
2 September, 1959.

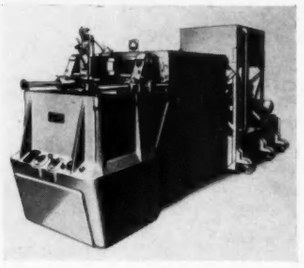
SEAWORTHY REACTOR

SIR, Your leading articles " Nuclear Rebellion " (7 August) and " Starting from Here " (28 August) state what has for far too long been left unsaid, in the hope of selling more descendants of Calder Hall. This hope has faded and the coal surplus makes this moment ideal for lessening our dependence on oil. The time is ripe for the United Kingdom to sponsor a reactor project for ship propulsion. British atomic policy to date has met the shore power demand but at the cost of failure to provide for the sea. This is a pity when the prosperity of the country depends so greatly on the strength of our marine and shipbuilding industries, and of our shipping trade. Unless we now get started in earnest on nuclear marine power we may be right out of the market for building the best ships in ten years time. I am, therefore, taken flat aback by your readiness " to abandon ship " in the interest of the power programme.

But, Sir, you need not yet don your Mae West. The Steam Cooled Heavy Water Moderated Reactor which Sir Christopher Hinton told the Select Committee it is desirable to build, lest the AGR lets us down, will, if the ideas of the " Seaworthy Reactor " are incorporated, be

SPARK EROSION MACHINE

Fast Metal Removal



THE new spark erosion machine illustrated is capable of machining forging die blocks of any size up to 28 in by 16 in by 15 in deep. It incorporates automatic controls obviating manual attention during operation and can operate at very fast metal removal rates.

The equipment, of which a prototype has been running for some time, is designed as three units: the machine tool, the generator, and the dielectric fluid circulator. Each can be sited according to shop layout. The units are all of the same width, which makes them particularly suitable for in-line arrangement.

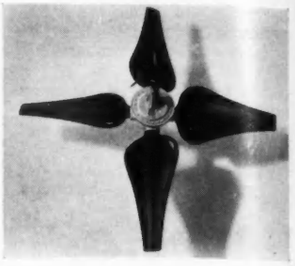
The machine tool itself has a main body cast in light alloy, the upper part forming the work tank, within which is the worktable. Rails mounted on the work tank carry a slide-mounted cross-rail which carries a servo head unit. The cross rail incorporates a worm and segment arrangement which enables the servo head to be pivoted up to a horizontal position, thus allowing unimpeded access to the work tank. The servo head is fitted with an automatic quill of 3 in stroke, driven by reduction gearing from a servo controlled electric motor. This is in addition to the manual control which allows 6 in of vertical movement. The quill can carry up to 20 lb of electrode.

Controls for operating the machine are few and simple. They are: an on-off push button, a three-position cutting range selector, a lever operated tank filling cock, a two-position switch for the quill, and an adjustment control for the servo.

The spark generator can be supplied for power consumptions of either 13 or 4·5 kW. Both generators give three cutting ranges, which allow, in the case of the larger generator, maximum metal removal rates of 1,000 cu. mm, 300 cu. mm and 100 cu. mm per minute. *Wickman Limited, P.O. Box 44, Banner Lane, Tile Hill, Coventry.*

INDUSTRIAL FAN

Hollow Plastic Construction



A SUBSIDIARY company of Imperial Chemical Industries Limited have acquired from the Hudson Engineering Corporation of Houston, Texas, the sole right to manufacture Hudson hollow plastic industrial fans in the United Kingdom. The fans will be sold under the trade name Marex.

Initially the range will consist of four-bladed fans ranging from 6 to 14 ft in diameter in increments of 2 ft. A set of hollow plastic blades may be fitted to two types of hub, either the auto-variable hub, which by means of a pneumatically activated diaphragm alters the angle of pitch while the fan is in motion, or the adjustable pitch hub, which requires that the fan be stopped while a simple manual operation alters the pitch. On both hubs the pitch angle is variable from −15° to +30°.

The advantages claimed for these fans over conventional wooden and metal types lie in the materials, method of construction and aerofoil shape. Blades are made of woven glass cloth and pigmented epoxy resin, laminated as a one-piece moulding. These materials make a self-coloured blade, which is resistant to both corrosion and heat, while the method of construction gives blades with a smooth surface, high strength, and low weight. They will not shatter or fragment and, being hollow, are extremely light; a set of blades for a 10 ft diameter fan weighs 58 lb. Following extensive wind tunnel tests, the blade contour—a true aerofoil section—has been determined to give optimum performance characteristics. Fan blades of the same size are readily interchangeable as all blades are works balanced to a standard value.

Installations in America and in this country are reported to be giving very satisfactory service, moving hot dry air through heat exchangers in desert areas, moving hot moist air from water cooling towers and moving corrosive laden air from process vats. *Marston Excelsior Limited, Wobaston Road, Fordhouses, Wolverhampton.*

Continuing Letters to the Editor

a very tolerable "harumfrodite, [shore plant] and sailor too." If it is made fit for sea it will also be suitable for supply to underdeveloped countries where highly trained engineers and physicists may not be available in every watch. It is well suited to enrichment by plutonium but, for the larger stations, can probably burn natural uranium, as Mr. Dannatt points out in his letter to you.

I am grateful to him and to Mr. Wootton for the interest shown in my articles published by you on 19 June and 7 August. My introduction was not meant to nobble other starters in the Galbraith stakes but to explain the reasons for our selection, which I find impossible to do without mentioning my objections as a marine engineer, intuitive if you like, to otherwise attractive types.

The steam-cooled reactor is the only design study which is not an adaptation of a shore reactor but in which every feature from start to finish has been selected for seaworthiness, not only to stand up to motion, collision, stranding or even sinking, but also to operation and maintenance, including fuel changing by sea-going types—the fool of the family may still be sent to sea.

Complexity of pipe systems matters little; of mechanisms, particularly electric or electronic it matters much; so we should avoid scram rods, control rods and rotating machines inside the containment as far as possible.

Plenty of people besides Dr. S. G. Bauer, who has guided our work on the steam-cooled system, have worked out the physics of steam and heavy water but lack his engineering genius and have not seen that this type of reactor is so promising for sea. Dr. Wootton has hoisted in what I meant when he says their brain child has a fine tradition (as indeed has Windscale, may we say?), but is not from a great Naval family. Is it not high time we started a British marine reactor family and stopped hoping that some by-blow from the power station programme may prove to have webbed feet?

Mr. Dannatt can rest assured that the success of British companies in gas turbine work has not been overlooked. I said that Auris is a lone swallow, and Shell announced last week that they do not intend to repeat her gas turbine installation, so my intuition is one up there. Closed-cycle gas turbines (unless using air) are even less suited to propelling merchant ships than open-cycle because of logistics of the gas supply. In open-cycle gas turbines, gas leakage has never mattered vastly but it may do so when fission products leak out too. The advantage of steam over a non-condensing gas is that it is much easier to prevent or catch leaks if the fluid can be readily condensed and most of the fission products will remain in the water in solution or suspension. In the indirect cycle, by our use of thermocompressors, we have avoided all rotating shaft glands subject to steam pressure but with gas I do not see how to avoid the use of blowers. In a direct cycle, the gas turbine will have shaft glands on turbines and compressors; the steam turbines will have turbine glands only.

In a ship a great bugbear is a seawater leak into the feed water. In a direct-cycle boiling water reactor the salt would go straight into the reactor, save a fraction caught by the ion-exchange loop. The main excitement then would be whether the ship was immobilised by priming from the increased density or by chloride attack on the stainless steel cladding. In the SCHW reactor we shall put a drum in our primary steam generators, through which we can blow down any salts. The steam from the drum will pass through the superheater before going to the thermocompressor nozzles so there should be no carry-over to the reactor. We are not so worried about fission products as we can detect and remove a faulty fuel element from the reactor quite simply before it can cause much activity in the primary circuit.

At this stage, arguments about fuel enrichment, burn-up and costs, are apt to be based on different premises and must be largely guesswork. The reactor with the best moderator and the best overall thermal efficiency will win on costs in the end if all are fully developed.

Policy towards nuclear ship propulsion has been so niggardly that we should be wise to select for our first ship a type of reactor system which we can confidently feel will develop into a world beater. An interim type, installed for the sake of getting a nuclear ship to sea, may prove sterile like the Auris, a great technical achievement but never likely to be repeated. Sea experience with one reactor may not be applicable to a different type and a wrong choice which requires too much maintenance, too long for fuel changing, too skilled a crew or, above all, which breaks down, will create long-lived prejudice against all nuclear propulsion. We can afford a stop-gap only if we can be absolutely sure we have the money to go ahead with the world beater at the same time and at full speed. Otherwise it is better to be a year or so later in launching our ship. I fear that the purchase of a US design for, or licence to build, a reactor for the first British nuclear merchant ship as well as for Dreadnought will be another shrewd knock, and mean that foreigners will naturally rather buy from the licensor who will have much more experience and prestige. The prestige to be gained by getting a ship to sea with a US design of reactor is doubtful, and may well be negative.

Senator Johnson has just laid a Bill before Congress to subsidise up to the hilt all private builders of merchant ships. Surely we can summon up enough money and courage to build just one entirely British nuclear merchant ship?

Yours faithfully,
CAPTAIN H. F. ATKINS.

Vickers Nuclear Engineering Limited,
Broadway, Westminster, London, SW1.
2 September, 1959.

New Plant and Equipment

DUAL-ROLE LORRY

Blown Discharge or Flat Platform

A BLOWN-DISCHARGE bulk container (introduced last year as a detachable container for fitting inside the body of a slightly modified tipper vehicle) is now available in an alternative form.

The Mk II version consists of a standard tipper chassis and cab, equipped with a detachable tipping or a flat platform body (or both) which may be removed completely from the chassis and replaced by the container, or vice versa. The entire conversion takes as little as eight minutes when suitable lifting gear is employed. The principal advantage of the latest multi-purpose version is that it dispenses with the surplus weight (8 cwt) of the body when the vehicle is being used in a bulk-container role. In other respects, the new version is very similar to the Mk I, the same system of male and female truncated pyramids (locked by quick release pins) being used to secure the container, tipper or platform body to the chassis sub-frame and a Wellworthy-Ricardo blower being fitted to permit pressure discharge.

Originally developed in collaboration with the Ketton Portland Cement Company (who already have 13 of them in use) this "tip and blow" container vehicle has since been used successfully with lime, sugar, flour and various other dry powders and granulates.

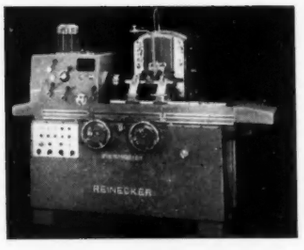
Sam. Longson Limited, haulage contractors of Chapel-en-le-Frith contractors to the Lime Division of Imperial Chemical Industries Limited, have been operating one of these container vehicles for some time and have recently found it invaluable as a "feeder" vehicle, employed in conjunction with an agricultural lime spreader. *Bonallack and Sons Limited, Basildon, Essex.*

BACKING-OFF MACHINE

Productivity Raised

RECENTLY designed and developed by Messrs. Reinecker of Einsingen, West Germany: an electro-hydraulic automatic backing-off machine—system Geyer. It is intended as a high production machine for the accurate generation of the clearance angle on such components as hobs, thread cutting, tools, etc., in the most economic manner. The hobs, thread milling cutters, form milling cutters and so on can have straight or helical flutes, and radial and angular relieving can be accomplished on this machine.

The automatic sequence of the operation (which cuts out a lot of unproductive time) allows the fastest cutting speeds to be adapted to a given material because of the exceedingly high productive capacity of the machine. The sturdy design and smooth action under all conditions makes for the highest possible standards of precision and surface finish. The versatility of this machine



renders it suitable for a wide field of application.

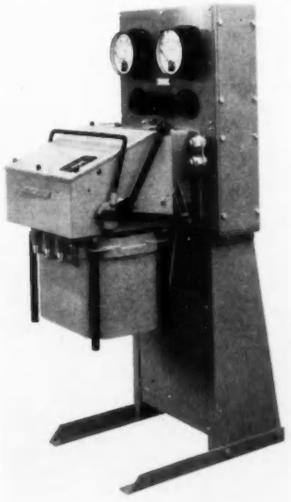
The high cutting speed of the backing-off tool is through a crank driven ram, suspended by tension springs to counterbalance the weight. Cross feeding of the backing-off tool for stock removal can be done by hand or automatically. The clearance angle on the component is generated through a cam controlled movement of the ram head slide. An arbour is held between two supports, and accommodates the workpiece. The left hand end of the arbour fits in a No. 5 MT socket in the work spindle. *Stuart Davis Limited, Much Park Street, Coventry.*

CIRCUIT-BREAKERS

Designed for Reliability and Economy

THE FD4 oil circuit breakers and units, rated at 800, 1,000 and 1,200 amps, are an extension to the well established range of Type FD medium voltage switchgear. The circuit breakers have been designed for reliability and economy, with the requirements of industrial and commercial power control particularly in mind.

The main contacts are silver plated and have a definite wiping action, with the final contact area well away from the initial contact make-and-break area. This action (together with the use of arcing tips) ensures that contact burning, due to load breaking and fault circuit interruption, is well away from the final contact area. Overheating and deterioration of the contacts when carrying full rated current cannot occur therefore as a result of contact burning or pitting. The use of silver surfaces on the main contacts and on the isolating contact also provides improved reliability. *Ottermill Switchgear Limited, 82 Victoria Street, London, SW1.*



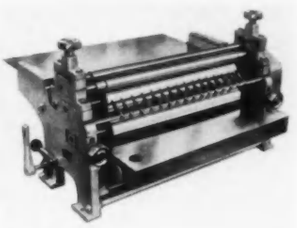
LABEL GUMMING MACHINES

Whole Surface Glued

JUST introduced to the British Market: the Essor Zephyr series of whole surface gluing machines and the Tempo Universal gluing machine with built-in conveyor belt.

The Zephyr series consists of three models. All are for whole surface gluing and employ the two roller coating system with easy adjustment for glue coat thickness.

No. 1 (shown here) has 2½ in diameter glue rollers and can be supplied either for hand operation or with built-in electric motor drive. The working widths are: 8, 12, 16 and 20 in. No. 2 has 3⅜ in diameter glue rollers but is supplied with built-in electric motor drive only. Facilities are also available for its use with hot glue by means of gas or electric heating with an adjustable glue tank. It is ideal for the gluing of cardboard, leatherette and canvas, a special pressure roller device being provided for easy change over from one material to another. It can be supplied either for bench mounting or with a cast



iron underframe. No. 3 is a somewhat heavier built machine than No. 2 but with the same features. It is suitable for use with either hot or cold glue, the glue rollers having a diameter of 3⅛ in. It is available with built-in electric motor drive only.

The Tempo (not shown here) is a fully automatic universal gluing machine with permanent built-in conveyor belt. It is suitable for larger work than can normally be handled by the hand labelling methods. The "A" model is supplied with working widths of 200, 300, 400, 500 and 550 mm. *Leon Davis and Company Limited, 32 Holborn Viaduct, London, EC1.*

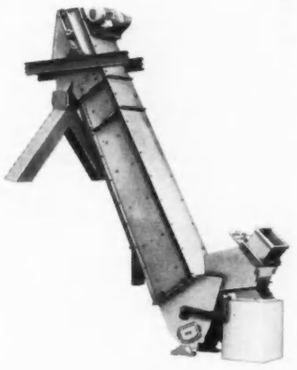
NOVEL ELEVATOR

Simple Design Uses Standard Components

ONE of the biggest problems in industrial boilerhouses today is the manual handling of coal. Firms spend large sums of money equipping their boilers with the latest types of mechanical stoker (with the object of improving efficiency) but leave their fireman to spend time and energy manually shovelling coal into the stoker hoppers. How much better it would be if the fireman could devote all his attention to ensuring that the fuel is burned efficiently.

It is with this object in mind that the 8 in Universal Elevator—an entirely new concept in design—has been produced. Standardisation is the keyword and this has resulted in many advantages not possessed by other types of elevators. Any length of casing (for any inclination between 60° and vertical) can be built from a series of standard components and the design is so simple that a complete machine can be bolted together and lifted into position in a matter of hours.

Not only does standardisation make



for greater reliability but it means also a low initial price and low maintenance cost.

The elevator is of the familiar chain and bucket type, but here all similarity to conventional design ends. *Bennis Combustion Limited, Little Hulton, Walkden, Manchester.*

DIRECT BURIED TRANSFORMER

With Cooling Unit

A NEW development is announced in the production of direct buried distribution transformers. This type of equipment has been supplied for many years but by the arrangement of an associated cooling unit above ground much larger capacities are now available. Installation of the first of these was carried out recently with the cooperation of the Eastern Electricity Board at their Edgware, Hendon District.

The main feature of the equipment is the use of a standard oil-immersed core and coil assembly to give the advantages of high reliability and economy. The transformer is of 500 kVA capacity, with a voltage ratio of 11,000 to 433. Tappings are provided at plus and minus 2½ and 5 per cent to a link board, access to which is gained through a handhole in the lid. *Hackbridge and Hewittic Electric Company Limited, Walton-on-Thames, Surrey.*

GAS REGULATOR

Content Indicator Replaces Gauge

A NEW regulator for gas welding equipment incorporating several novel features has been produced by British Industrial Gases Limited. It is one of the results of a revised agreement between the company and the Harris Calorific Company of Cleveland, Ohio.

The regulator is claimed to overcome the two principal reasons for damage and inefficient working, namely, damage to gauges and damage to seats and diaphragms, due to improper operating procedure. In order to get these results the cylinder pressure gauge has been replaced by a cylinder content indicator.

The cylinder content indicator is graduaged in steps, namely, full, ¾ full, ½ full, ¼ full and flush, when empty. It is interesting to note that the indicator is flush (with no part protruding) when the regulator is removed from the cylinder, and thus is not subject to damage in transit.

The working pressure required of the regulator is selected by screwing in the adjusting screw to the desired pressure shown on the bonnet. This feature is only possible because the regulator is designed to deliver constant working pressure regardless of incoming pressure, and a minimum variation from flow to no-flow. That is to say, once the regulator is set, the delivery pressure will remain constant from when the cylinder is full to when it is empty. *British Industrial Gases Limited, 700 Great Cambridge Road, Enfield, Middlesex.*

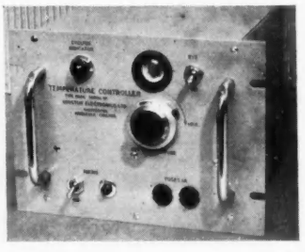
TEMPERATURE CONTROLLER

High Sensitivity

TEMPERATURE can be controlled electronically to plus or minus a quarter of a degree at 1,000° C and above with the recently introduced Winston-United Steels precision temperature controller.

The direct calibration of operating temperatures has been made possible through the use of improved multi-turn potentiometers. Any desired range up to 1,200° C may be used and a direct calibrated range of 1,000° C in ¼° steps is provided. The device is said to be capable of continuous use for several years with a total shut-down time of only a few hours.

The circuit consists of a platinum resistance thermometer formed into an a.c. Wheatstone bridge, the pre-set arm of which is a 1,000 ohm potentiometer graded in 4,000 steps. The out of balance voltage from the bridge is amplified in two stages to give a gain of about 2,000. The degree of out of balance is displayed by a " magic eye " indicator which has two ranges of sensitivity.



The amplified output is also fed to a phase sensitive bridge which gives a positive or negative output according to whether the furnace temperature is lower or higher than correct setting. This output is amplified ten times by a d.c. amplifier and then applied to one section of the relay controlling the furnace. A time interval generator then provides switching cycles (normally 30 sec) to the other section of the relay so that the first section conducts only when the thermometer control signal is more positive than the time generator signal. When the furnace is at the correct temperature the relay is energised for only half the cycle. *Winston Electronics Limited, Shepperton, Middlesex.*

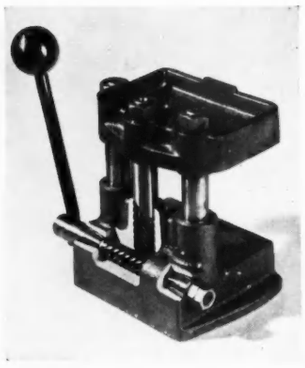
JIG CLAMP

Effective Locking Action

COMING on to the market this month is a new clamping jig, made in this country under licence from the N. A. Woodworth Company of Detroit, U.S.A.

The Cone-Lok, as the device is called, is claimed to be the simplest work-holding jig available to industry, and makes use of the highly effective locking power of perfectly mated male and female cones. The male cone is formed on the horizontal pinion shaft, and fits into the famale cone which is an integral part of the base. Two such sets of cones are used, one on each end of the pinion shaft. A smooth locking action is transmitted by helical pinion and rack. The jig is designed so that all its working parts are adequately protected; and chips, cutting oils and other foreign matter are prevented from coming into contact with the moving parts.

Other novel features of this jig, it is stated, include its low number of parts, its sealed lubrication system which leads to low maintenance cost and long service life, and its double locking action.



The jig is claimed to be a time and money saver, because only one unit is required for many different jobs. All that is needed is a series of appropriate bush-plates, thus cutting down the need for single purpose jigs. There are five models in 18 sizes from 1 in by 1 in to 12 in by 9 in work areas. *F. Pratt and Company Limited, Park Works, Halifax, Yorkshire.*

FAULT DETECTOR

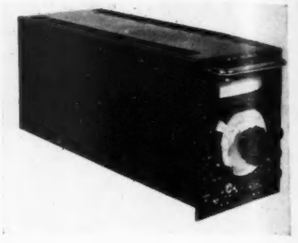
High-Voltage Power Lines

AN electronic fault detector has been developed in cooperation with the North of Scotland Hydro-Electric Board to facilitate rapid location of faults occurring on 132 kV lines.

The detector works on the radar principle of pulse reflection and is of the d.c. type. In this type of locator, faults can only be found on a dead line (a.c. types can be used on live lines), and can therefore detect only sustained faults and not those of a transient nature. It has an advantage over the a.c. type in that it is portable whereas the a.c. type is usually permanently sited because of coupling difficulties inherent in its design.

The new detector has performed well under test conditions with the North of Scotland Hydro-Electric Board. It has successfully located staged faults under varying conditions and it is hoped that it will be able to detect the onset of icing conditions on the line before the lines sag sufficiently to touch the ground.

Further development is proceeding on an a.c. locator, in order that faults of a transient nature can be dealt with. A fault of this sort occurs when lines clash in a high wind or when lightning strikes the line. This locator will be designed to cope with fault conditions on both 132 kV and 275 kV lines.



There is no difficulty in attaching these locators to lower voltage systems, such as 33 kV and 11 kV lines. However, with these lines considerable practical difficulties of interpretation exist due to the many side-spurs which " tee off " at fairly frequent intervals. Each of these spurs causes multiple reflections, which tend to confuse reflection from the actual fault. *Ferranti Limited, Edinburgh, Scotland.*

INDUCTION FURNACE

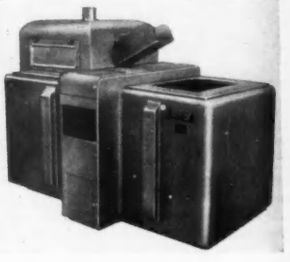
Holds Two Metals

A LOW frequency, two chamber induction furnace for the simultaneous melting and holding of copper and aluminium, as well as their alloys, has been introduced.

This type of furnace is said to be particularly suitable for small die casting foundries where it is considered desirable to limit the number of separate melting furnaces. By dividing the furnace into two separate compartments it is possible, when melting, to maintain close temperature limits in the holding chamber.

The furnace body, which consists of two melting chambers with a common inductor coil, has a welded casing of sheet and structural steel. The melting chamber is connected to the holding chamber by two oblique channels which can be cleaned without difficulty during operation.

Provision has been made for automatic temperature control to ensure constant temperature in the furnace chambers. Thermocouples are located in suitable places in the furnace wall and are cast into a ceramic material which has been specially developed to withstand high temperatures and the corrosive effect of the melt.



The furnace transformer, which is common to the two chambers, is provided with a butt-jointed core and primary coil for direct connection to the network. The primary coil is wound with square section copper wire and insulated with glass fibre tape, specially treated to withstand continuous temperatures of up to 400° C. A capacitor bank is provided to give a power factor of 0·9. *Fuller Electric Limited, Fulbourne Road, London, E17.*

WELDING MACHINE

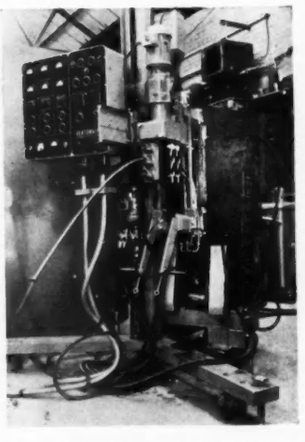
Thick Welds in One Run

AN entirely new automatic vertical slag welding machine known as the Vertomatic has been introduced into this country. It is based on patents held by Vus (Bratislava).

The machine is designed to weld plates of up to 14 in thickness and is said to provide considerable economies over other methods when welding thicknesses of over 2 in. The principle behind the process, which was first developed in Russia, involves the fusion of the parent metal and continuously-fed weld metal under a substantial layer of high-temperature electrically conducting molten slag.

In order to carry out a weld the plates are set up in a vertical plane, and the square cut edges to be welded are positioned parallel to one another.

The weld metal is led to the fusion zone from a coil and holds its own flux, which is a mixture of ferro-alloys and is, perhaps, the crux of the process. Until Rockweld introduced the machine, this method of welding gave a very poor impact strength, but sample welds carried out on this machine have given Charpy keyhole impact values of between 36 and 50 ft-lb. *Rockweld Limited, Commerce Way, Croydon, Surrey.*

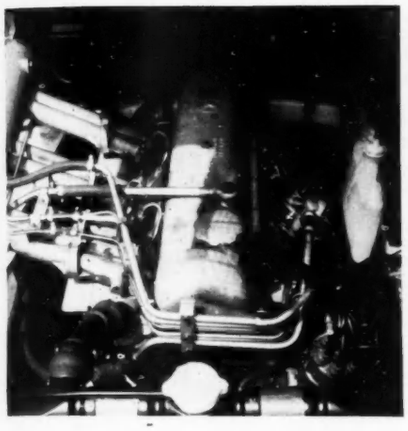


MERCEDES-BENZ LATEST 220 MODELS

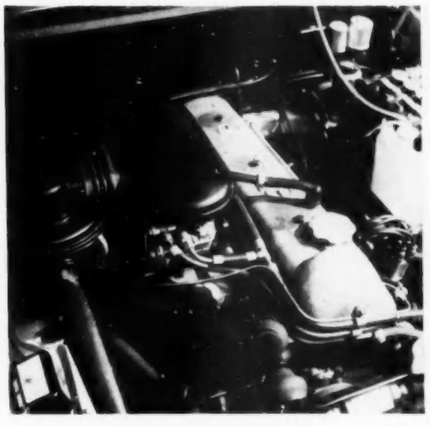
By Gordon Wilkins

A remarkable standard of steering, road holding and riding comfort have been achieved on the new Mercedes-Benz 220 saloon models. They have an entirely new saloon body of unit construction, longer, and wider, with more space for passengers and almost a 50 per cent increase in luggage space. The structure is lighter and stiffer than before, but as the glass areas are increased, total weight is slightly higher.

The all-independent suspension is a further development of the system Daimler-Benz have been using for years, and incorporates the results of their racing experience. The Fahrschemel, or flexibly mounted sub-frame carrying the front suspension has proved its value in isolating the main structure from road shocks and vibration, but as on several other makes, it introduces a certain vagueness into the steering. This has been countered by a new mounting method. The weight of the car is taken on two conical rubber mountings, fairly flexible axially, but stiff radially. Braking reaction and major road shocks are resisted by two horizontal spring steel blades extending forward to rubber-bushed mountings on the main structure. The steering gear and its linkage have also been stiffened.



The 220 SE has straight air pipes, 300 mm in length, connected to the main air trunk. A two-plunger injection pump provides intermittent injection into each of the six inlet ports.



The 220 S has a continuous circulation of fuel to the float chamber and back to the tank to prevent vapour lock. At full throttle, a valve closes the return line to reduce the load on the pump.

Front suspension has been redesigned, with a greater difference between lengths of upper and lower wishbones, raising the front roll centre from 1·18 to 5·1 in above ground level and very long telescopic dampers are now fitted as close to the wheels as possible. Rear suspension is of the well-known single-pivot swing axle type, but it now has the transverse compensator spring to reduce roll stiffness, already employed on the 300 SL sports model.

The engine is basically the same in-line six, of 2,195 cc., with single overhead camshaft but the valve gear has been redesigned. The fingers between camshaft and valves are now mounted on separate ball joints instead of on a rocker shaft, reducing weight of moving parts and giving a better angle of attack. Exhaust valve lift has been increased, and it has been possible to raise the safe revolution limit from 6,000 to 6,500 r.p.m.

The simplest version, the 220, has two downdraught carburettors and gives 105 b.h.p. SAE (95 DIN) at 5,000 r.p.m., with maximum gross torque of 133 lb-ft at 3,300 r.p.m. This model replaces the former type 219. The next model, the 220 S has two twin-choke downdraught carburetters. The second throttle on each carburetter has a weighted throttle which is opened by induction depression when full power is required. To prevent vapour lock, there is continuous circulation of fuel to the float chambers and back to the tank, but at full throttle a valve closes the return line, to reduce the load on the pump. This engine delivers 124 b.h.p. SAE (110 DIN) at 5,200 r.p.m., with gross torque of 139 lb-ft at 3,700 r.p.m. It goes in a car with more luxurious finish and equipment.

The third version, the 220 SE, has intermittent injection into the inlet ports from a two-plunger pump and gives 134 b.h.p. SAE (120 DIN) at 5,000 r.p.m., with torque of 151·8 lb-ft at 4,100 r.p.m. Compression ratio on all engines is 8·7 to 1.

Transmission is through a four-speed all-synchomesh gearbox with steering-column lever. About 20 per cent of production is now ordered with the Mercedes automatic clutch, which is combined with a fluid coupling. Like other manufacturers selling automatic clutches, Daimler-Benz have found that some drivers, Americans especially, tend to treat them as automatic transmissions, leaving the gear lever in top even when starting. On the Mercedes design this can overheat the fluid coupling rather than burn out the friction clutch, and there is a warning light signal on the instrument panel, telling the driver to change down, which shows when the casing temperature reaches 110° C, which implies a fluid temperature of about 180° C.

Mercedes still refuse to adopt disc brakes, but are now using Alfin drums with turbo cooling fins for their front brakes. On the 220, with no servo, pedal pressures are high, but other models have servo assistance and the brakes show high resistance to fade. Special nylon-carcase tyres of 6·70-13 have been developed for the new models by the German Dunlop factory.

New safety features include a steering wheel with large padded centre, and padded frame to the instrument panel. Interior door handles are recessed into the doors, window winder handles are padded and switches have flexible tops. Air exit louvres are concealed behind plated strips on the rear quarter panels, as a contribution to draught-free ventilation, and a means of relieving air pressure when a door is closed quickly.

Daimler-Benz development engineers have concentrated on producing a car which will remain under control in the common case of a sharp swerve to avoid an obstruction, followed by a counter swerve to keep the car on the road. They marked out a tight S-bend with rubber pylons, within a width equivalent to one track of an *autobahn*. Rudolf Uhlenhaut, the development engineer responsible for racing and passenger cars, could take a Grand Prix single-seater through it at 90 m.p.h. After two years of development the new saloons go through at about 75. Experiments with other cars have provided many spectacular failures, the understeering models tending to go straight on, the oversteering cars spinning out on the second swerve. In another test, on a special skid pad made of slippery cobblestones, the Grand Prix car cannot keep up with the new saloons. The handling characteristics are neutral, tending to slight understeer.

New unit construction body has more passenger space and nearly double the luggage room of previous models.

Kerb weights of the three models range between 2,890 and 3,000 lb.

VOLKSWAGEN IMPROVEMENTS FOR 1960

The road holding qualities of the Volkswagen have been improved by adding an anti-roll bar to the front and by a different mounting for the engine-transmission unit at the rear. The front roll bar, installed in *de luxe* sedans and convertibles, reduces sway and oversteer. The entire engine-transmission unit is now given a two degrees downward tilt towards the front, bringing the centre of the differential 0·6 in lower. This feature will tend to give the rear wheels a slight inward camber and improve their cornering power.

There is a new two-spoke steering wheel with recessed centre and a half horn ring. The *de luxe* sedan now has a padded sun visor instead of the plastics type previously used and all external door handles are now of the fixed type with push buttons. Improved locks and striker plates make the doors easier to close. Direction indicators on *de luxe* sedan and convertibles are now self cancelling. Efficiency of the wind-shield defrosters has been improved by using larger diameter front heating pipes. All Volkswagen engines now have fan belts suitable for tropical climates previously only available as spares. Generator output has been increased from 160 to 180 watts to ensure quicker battery charging and permit use of additional electric equipment.

Front seat comfort has been improved by changes to the backrest, spring case and upholstery padding, and by an inclined foot support and an armrest with grip recess. Sound absorbing materials are used more generously in body and frame, the gearshift rod coupling is softer to reduce sound transmission and fan noise has been lessened by reducing fan revolutions. There are new colours and upholstery patterns.

Karman Ghia Volkswagens now have a windshield washer as standard equipment and a headlamp flasher button is built into the end of the direction indicator lever. Tail, stop indicator lights are of new shape with separate bulbs for each. There is now an armrest on the driver's door and the rear quarter windows are now hinged to open outwards for better ventilation. Front wings are modified to carry the headlamps 1·8 in higher and further forward. The wheel arch has been slightly increased and the intake grilles for the fresh air system have been substantially enlarged. To meet the challenge of new competitive cars which require little maintenance or none at all Volkswagen have introduced revised schedules eliminating maintenance at 1,500 miles intervals. Lubrication is now recommended every 1,500 miles; maintenance every 3,000 miles.

Anglo-American Aluminium

The latest joint Anglo-American enterprise in the manufacture of aluminium products is beginning to take shape. The Imperial Aluminium Company Limited (Impalco) was formed last June when the Aluminum Company of America and Imperial Chemical Industries entered into an agreement to collaborate in wrought aluminium production. The new company, which is owned jointely by ICI and Alcoa in the ratio of 51 to 49 —leaving control in British hands—will take over ICI's aluminium plants at Waunarlwydd in South Wales. The board of Impalco consists of three members from ICI: Dr. James Taylor (chairman), Mr. Berkeley Villiers (managing director) and Mr. Michael Clapham, and two from Alcoa; Mr. Du Bose Avery and Mr. F. J. Resch.

Dr. Taylor has been a member of the main board of ICI since 1952 and is responsible for the metals and explosives activities of the company. He was formerly joint managing director of Nobel division, which he joined in 1928 as a member of the research department. Mr. Villiers has been commercial director of ICI Metals division since 1953 and had been a member of the company's sales organisation since 1934. Mr. Clapham, who is a classics scholar of Cambridge University, has been joint managing director of ICI Metals division since 1952. He is also a director of Pyrotenax Limited.

Alcoa supply a salesman, Mr. Dubose Avery and an engineer, Mr. Fred Resch. Mr. Avery has been elected a vice-president of Alcoa International Incorporated, and will make his headquarters at a new office that company is to open shortly in London. Mr. Resch, formerly chief industrial engineer for the fabricating division of Alcoa's Tennessee operations, will be based at Waunarlwydd and will be concerned primarily with the manufacturing activities of the new company.

New Products from US Steel

The troubles that America's leading steel companies have encountered during the past two years have hardly had an effect on their research and development activities, except perhaps to intensify them. US Steel, who account for 28·4 per cent of the entire industry in the United States, listed in a recent publication the new products and processes which are becoming available as the climate of business improves.

The long list of items includes the following: a further development of the hydrospinning process for production of missile and rocket components; new processes for the production of extremely thin stainless steel and super-alloy strip useful for supersonic aircraft and also missiles; direct reduction processes to reduce iron from ores without melting (these techniques received increased attention during the year); US Steel's new basic roof programme for open-hearth furnaces, which has been a very successful development; also, increased use of oxygen in the open-hearth process which has led to many new production records; a new high strength, steel alloy called USS Airsteel X-200 for use in missiles and aircraft; vinyl-coated sheets in many colours and patterns, which lend themselves to a wide variety of uses, such as television cabinets, wall panels, doors, and so on; further development of aluminium-coated steel sheets for use by the automotive industry in mufflers; a superior quality, grain-oriented electrical sheet (the steel is pressed so that its crystals are aligned to aid in conductivity and in other qualities important in electrical applications; and improved steels and welding techniques for nuclear power use, such as giant forgings for America's first nuclear powered aircraft carrier.

US Steel have also developed a new chemical surface treatment for tin plate, resulting in improved shelf life for food containers. Considerable emphasis is being placed on coated sheets using both the rarer non-corrosive metals and the newer plastics. These products should considerably strengthen the position of the steel industry throughout the world *vis-à-vis* competing materials and give users a much improved choice.

Research facilities have also grown considerably. A new electromechanical building was started late last year " for the study and development of new types of controls and advanced instruments " to improve the yield, quality and uniformity of the company's products. A new casting plant was installed to handle multiple-size ingots in vacuum metallurgy, particularly important for very large forgings for rotors and generator shafts. Another unit, a consumable electrode vacuum furnace, produces ingots up to 5,400 lb in weight. All these developments have been affected by the participation of the steel industry in space engineering. They will benefit traditional industry just as much.

British Airways Prosper

The performance of British European Airways in 1958-59, when they made a small profit of £232,695 was better than that of most other airlines. It was made during a world-wide depression in air travel and a serious fall-off in expected traffic. The corporation's report and accounts for the year ended at 31 March states that sales rose by 7·2 per cent whereas the capacity offered for sale was up by 13 per cent so that 60·4 per cent of capacity was sold compared with 63·7 per cent the previous year. In addition to this large loss of income due to the depression—equivalent to £1½ million—last winter's fog cost £250,000 in profit.

The world's scheduled airlines as a whole increased their business by 5 per cent in 1958 while their capacity was up by 10 per cent. Together they made a net loss: they spent 4 per cent more than they earned. BEA are therefore in a relatively strong position. To some extent this was due to the prompt cost saving adjustments including a virtual stoppage of recruitment. The corporation carried 2,828,715 passengers during the year and flew nearly 731 million passenger miles on international routes and 257 million on domestic routes. They now propose further fare reductions to stimulate demand for their services. They would like to see economies on European tourist class services to bring them into line with " economy " class services on the North Atlantic " and state that it is their intention to make greater use of differentials between fares available at different times of the day, of the week and of the year." Cheaper fares will be introduced at the beginning of next summer. They do not fear competition but unfortunately will be slowed down in their enterprise by the slower pace of others.

Rotodyne Assured

On the eve of Farnborough it became known that the Fairey Rotodyne vertical take-off air liner is to receive the government aid of a Ministry of Supply further development contract. Negotiations for buying a military version of the straight-up aircraft were announced by the Minister of Supply in July. With British European Airways discussing a possible requirement of 20 Rotodynes, a Fairey spokesman could well say that development of the airliner is now assured.

Winged Executives

What was described as " the fast-expanding business flying sector of commercial aviation " has become a new field of activity for Sir Robert McAlpine and Sons. McAlpine, who have operated their own executive planes for nearly 14 years to carry their staff all over the country, intend to put their experience and aircraft " at the disposal of industrial firms and commercial enterprises in Britain and Europe." Already they have advised several British companies in the economics of business flying. The manager of the company's air service, Mr. Raymond Young (a former airline pilot who has been handling McAlpine's aviation activities) expressed the company's convictions that " as road congestion increases, and the flow of cars on the roads exceeds the highway building programme, we are convinced that only a major increase in business flying can keep industry's generals mobile."

McAlpine's have recently bought an Italian Piaggio P.166, a type becoming increasingly popular for executive flying, and in the first six months of this year, with this aircraft and others, the company had flown some 285 hours on 594 journeys. This aircraft, sold in this country by Aero-Enterprises (Boreham Wood) Limited, costs £31,610 (basic price without duty) f.a.f. Villanova d'Albenga Airport. McAlpine state that the cost per seat mile can be as low as 7½*d* on a yearly utilisation of 200 hours, or down to 4½*d* on 400 hours, in each case filling all four seats. The company will not only advise on all aspects of business flying from choice of aircraft and pilot to running costs, maintenance and availability of landing areas, but will " lease " aircraft to interested firms at a set fee per flying hour, giving them an option to buy.

These developments are underlined by the request from John Blackwood Hodge and Company, of Berkeley Square, London, W1, for McAlpine Aviation to supply a Piaggio P.166 executive aircraft.

Strength of Metal

Improved results and growing financial strength are the keynotes of the statement of Sir Charles Westlake, chairman of Metal Industries Limited, who have become one of the largest switchgear manufacturers in the country with a substantial stake in hydraulic and other engineering fields. Trading profits before tax were £250,000 higher at £1·76 million.

Scotch and Polyethylene

The Distillers Company Limited are taking a major part in the Scottish Industries Exhibition, as might be expected from a company so much concerned with production of Scotch. The whisky and industrial activities of the group are featured quite separately, emphasising the considerable progress which has been made by the industrial division of the group. The main theme of the industrial group exhibit is the development in the past ten years, of their petroleum chemical activities at Grangemouth in partnership with British Hydrocarbon Chemicals and the British Petroleum Company. A scale model of the Grangemouth site, housed in a globe some 10 ft in diameter, and visible through a series of portholes, is the highlight of the exhibit. Sectional displays illustrate the processes in use and the production methods, properties and uses of the many products made there, including phenol, " Rigidex " (a new polyethylene product), polystyrene plastics, solvents and carbon dioxide.

The emphasis is on new developments, such as the use of carbon dioxide in arc welding, the development of the company's continuous yeast process, the use of malt extract in the textile industry for de-sizing cloths after weaving and the uses of the new type of polyethylene they have developed, of a simple and regular molecular structure, with a softening point high enough to withstand boiling water.

Averys in Line

The high level of activity in the retail trade, coupled with a rising demand for automatic weighing, made the year ended 31 March a most prosperous one for Averys Limited. Profits before tax were £2·3 million. Their chairman, Mr. W. Leonard Barrows, pointed out that the sale of machines to industry is becoming a major activity, and that there is increasing emphasis on automatic production which is creating a demand for weighing as an integral part of the factory flow-line.

Far from Featherheaded

Bright and breezy as all the posters, paper napkins, flicker books and table mats of the Royal Society for the Prevention of Accidents' eighth National Industrial Safety Week gaily are, they light up a serious and important problem. Correct handling is the theme of this year's Safety Week, from 23 to 28 November. Lifting accidents still play their part in the grievous, costly field of industrial accidents where 665 deaths occurred in 1958, and 167,032 injuries in work places covered by the Factories Act, excluding coal mines and railways, were recorded.

"Correct handling eases effort" runs the slogan, and genuinely amusing cartoons and illustrations point the serious moral. The shock headed Mr. Featherwate, expertly balancing a one-ton weight on his left palm joins the ranks of the cartoonists' little men with big messages and may well stay long past November. Certainly RSPA hope that their exposition of kinetic handling, coordinated rythmic movement and using the muscles best able to tackle the job, will lead to a permanent improvement with fewer accidents and less fatigue at the end of the day. The society's good work penetrates not only far and wide in the United Kingdom. Overseas firms, largely those with British links, are also taking part in the Safety Week.

Another cause of accidents is the use of worn or out-of-date equipment. An individual firm, British Oxygen Gases Limited, of Spencer House, St. James's Place, London, SW1, is carrying out free-of-charge surveys of oxy-fuel gas equipment and reporting on condition and operating efficiency. One of the company's eight district managers reports that while it is impossible to say how many possible accidents have been prevented, it is surprising how often worn and obsolete equipment is found.

But to allow RSPA the last word. Not only those who have physical loads to lift may pause before the profound message of one of the brightest illustrations. It says—Think before acting.

Differential and Suspension

The strike of machinists at the tractor and transmission factory of the British Motor Corporation at Ward End, Birmingham, was a continuation of the trouble which began over the dismissal of a shop steward. Workers at the Morris radiator factory at Oxford passed a resolution last week expressing "grave concern" about what they called "the new wave of attacks on the shop stewards' movement by the BMC management."

The Ward End strike was started by 35 men who issued an ultimatum to the management giving them one hour in which to offer them interim piece work rates to increase their earnings. They complained that the management "appeared to have priced the new car without pricing the job." The strike was unofficial and eventually the men obeyed the order of the AEU executive to return to work pending negotiations. The result of this small strike was to bring the Austin Seven production line to a standstill and 2,000 men were sent home. Much of this is impatient bad temper on the men's part and the feeling they are being victimised and provoked. The management feel on their part that lack of discipline threatens to ruin all their efforts at efficient production planning. Perhaps the main components lacking are not so much differentials and suspension—in one sense familiar elements in motor car production—but mutual understanding and common sense.

Sports Car Nobbled

While the disputes at the British Motor Corporation's factories smouldered on, another quarrel threatened to wreck the production effort of David Brown Industries Limited at their Newport Pagnall factory, Buckinghamshire, where the Aston Martin DB 4 is built. Negotiations have broken down on production bonus times in the assembly section. Twenty men went on strike but, the management say, "the dispute will very quickly affect the employment position, livelihood and well being of all other employees." Fitters in the chassis assembly section have "refused to allow the management to study assembly procedure and fix realistic production bonus rates. Instead they have made demands for very high wages in return for less than average effort."

David Brown Industries wrote to all employees on the day the strike began (26 August) giving the facts leading up to the breakdown of negotiations. Theirs certainly appears to be a very strong case. It will be instructive to the whole industry to see how the men react and whether the National Union of Vehicle Builders will reply by presenting their own case. Meanwhile one of the most splendid sports cars Britain has ever designed lies unassembled.

Juvenile Stockpile

The sharp rise in unemployment in August almost entirely coincides with the increment currently created by the "bulge" of school leavers. The rise of 32,000, which once more brings the number unemployed well above 400,000, took place when adult unemployment actually fell—for the first time in August for four years—by 5,000. It is the increase of 38,000 in juvenile unemployment which is distressing. Employers are urged to "stockpile" juvenile labour if the pressing problem of finding work for the boys and girls expected to leave school over the next three years is to be solved. In 1962, when the peak is reached, as many as 701,000 school leavers will be coming into the labour market.

The answer suggested by the Carr Committee on recruitment and training of young workers in industry last year was an extension of the quantity and quality of apprenticeships. But the present trend in industry is to reduce the number of apprenticeship schemes. Youth apart, the unemployment situation in August appears fairly normal for the time of year, when seasonal employment tends to shrink sharply. Unfilled vacancies dropped by 12,000, rather less than is usual. The fact that some of the more notorious unemployment "pockets," such as Northern Ireland, are beginning to yield to treatment is distinctly encouraging.

Stout Hearts and Coronets

Advice on how to remain healthy and wise will be handed out to business executives at a one-day conference organised in London by the Chest and Heart Association. Their slogan is "prevention, research, education" and their activities are designed to promote health care. In the announcement of the conference they addressed themselves to the head of every business: "competition — exports — personnel problems — are pressing on his mind. He may worry, and his health may suffer—in ways of which he is hardly aware. Preserving health includes the handling of stress and responsibility. Wise medical advice can often prevent a breakdown."

Nine "outstandingly eminent" doctors will speak on stress and responsibility—their effect on body and mind; overwork and fatigue; exercise and holidays; business travel; high blood pressure and coronary thrombosis; chest disease in the middle-aged man; self-medication; facing an operation.

For as little as four guineas each, executives will be told what to do and how to do it. Morning coffee, lunch (with wines) and tea will be provided to minimise the shock. Lord Baillieu and Sir Richard Powell, both—one can assume—greatly in need of this kind of advice, will take the chair at, respectively, morning and afternoon sessions.

Science for Staff Officers

Two modifications are being made to the training of army staff officers in an effort to increase the proportion of staff officers with scientific knowledge. The first is that between 20 and 30 of those selected each year for the Staff College at Camberley will take a further year's technical staff course at Shrivenham at the Royal Military College of Science. This will give them a two-year staff course, half scientific and half general.

The second plan is for all officers at Camberley to complete a short Shrivenham course. At present only some Camberley students take a course at Shrivenham. The change is timely for it is increasingly difficult for a senior officer to exercise control of his command unless he has a grasp of basic knowledge concerning his technical equipment. It makes the beginning too of giving an officer a chance to earn promotion on his expertise and technical knowledge.

Flight Engineer

Air Vice-Marshal P. S. Blockey has been appointed senior staff officer, Royal Air Force Technical Training Command, as from 24 August. He has been previously director-general, aircraft research and development (RAF) at the Ministry of Supply since 1956.

He joined the RAF in 1924 and after flying with fighter squadrons he took an engineering course at the Home Aircraft Depot, Henlow, going on to graduate at Cambridge in 1933. He saw service subsequently with bomber squadrons and in 1940 he joined the Ministry of Aircraft Production after taking the RAF Staff College course. Thereafter he occupied a series of senior engineering positions in the service until he went to the Ministry of Supply in 1956.

Top Gas People

The new chairman of the Gas Council is a Cambridge graduate in engineering, an old Harrovian and a member of a family which has held high engineering and administrative posts in the gas industry for 125 years. Sir Henry Jones, who has been deputy chairman of the council since 1952, has been appointed to succeed Sir Harold Smith as chairman on 1 January, 1960.

Sir Henry's successor as deputy chairman is also an engineer with a distinguished career in the gas industry. He is Mr. W. K. Hutchison, who has been chairman of the South Eastern Gas Board since 1948, and is the current president of the Institution of Chemical Engineers.

Clutter Versus Litter

The Minister of Housing and Local Government has told local authorities that he believes commercial and other interests might be prepared to supply free litter bins in exchange for advertisements on them. The idea is a good one if the design and manufacture of the bins are up to a resonable standard and the advertisements are also acceptable. The bins would of course be most attractive as an advertising medium in those areas where there are most people in circulation; such areas are also likely to be most susceptible to litter.

Opinion on these matters varies widely from one area to another. Not all local authorities shared London's acceptance of variegated advertising displays on buses. Some of the biggest municipal transport systems have gone for years without a single display advertisement on their vehicles. This seems to be a good opportunity to unite public service, business enterprise and a higher standard of cleanliness in the streets.

ESCAPE AND RETURN

Plans for the First Ventures into Space as Described at the Recent Astronautical Conferences in London

ENGINEERS and scientists from all over the world have recently been in London attending three conferences on space research and engineering organised by the British Interplanetary Society—the first Commonwealth Spaceflight Symposium (27 to 29 August), the 10th International Astronautical Congress (31 August to 5 September), and the Second Space Law Colloquium (Lincoln's Inn, 4 September). Over 120 papers were read; some of the more important of those dealing with future engineering projects and programmes are reviewed in this article. Reports of achievements to date will be published in a second article.

International Congress

After the Congress had been opened by the Minister of Supply, Mr. Aubrey Jones, the inaugural paper was given by Dr. Hugh L. Dryden, deputy administrator of the United States National Aeronautics and Space Administration, who spoke on global aspects of the exploration of space. NASA's programme for the future includes the establishment of artificial satellites of the Moon, hard and soft landings on the lunar surface, and eventually study of the planets Mars and Venus. Communication satellites will be put in orbit round the Earth at a comparatively early date. Project Mercury (for launching a man-carrying space capsule into a satellite orbit, with return to Earth on command) will be followed by manned flight in advanced manoeuvrable vehicles, in larger satellites carrying several men, and in permanent orbiting space laboratories, by manned circumnavigation of the Moon and return, and by lunar landing and return. Dr. Dryden stressed the desirability of coordinating the various national programmes in the space field to avoid undesirable duplication, and of cooperative action in tracking satellites and receiving telemetered data. Discussions are under way between NASA scientists and their colleagues from other countries with a view to taking the ultimate step in international cooperation: joint participation in a single programme.

Particulars of the proposed manned lunar expedition were given later by M. W. Rosen and F. C. Schwenk, of NASA. This would use a five-stage vehicle (Nova) standing about 220 ft high and weighing 6,700,000 lb at launch. The first-stage booster would be 48 ft in diameter and be powered by six kerosene-LOX engines, each of 1·5 million lb thrust. It would contain seven 16 ft diameter tanks of each propellent. To simplfy production, the second stage would be made up of four of these tanks and a single 1·5 million lb engine. The third stage would also contain four 16 ft diameter tanks, but these would hold high-energy propellents; its four engines would produce 600,000 lb thrust and place the cone-shaped payload (fourth and fifth stages) in its cislunar orbit.

On approaching the Moon, control jets would be used to orientate the cone for the descent, and the four variable-thrust, high-energy-propellent engines of the fourth stage used to brake the vehicle. To facilitate choice of landing site, sufficient propellents for one minute's hovering above the lunar surface would be provided. Landing would be on retractable legs.

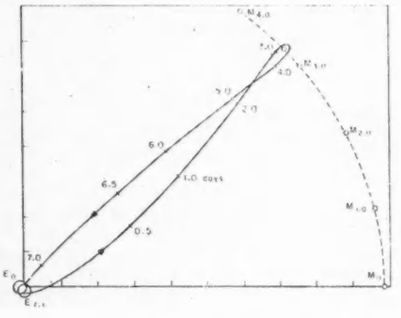
The payload placed on the Moon would have a mass of 36,000 lb and consist of the spent fourth stage, the fifth stage engine and the manned capsule, which would be an enlarged version of the one to be used in Project Mercury. It would be a truncated cone, height 14 ft, maximum diameter 12 ft, attached to the top of the cylindrical fifth-stage engine, which would be fitted within a central cylindrical cavity in the fourth stage. After twelve days' exploration of the Moon, the fifth stage engine would be fired (rollers being fitted to facilitate its sliding out of the landing vehicle) and the capsule return to Earth.

The capsule would be covered with an ablative material to remove heat generated during re-entry, and parachutes would be employed to effect landing in the ocean. There would be two levels inside the capsule, the lower being the cabin (fitted with an airlock for use on the Moon) and the upper containing food, power supplies, tools and so on. The second, third and fifth stages are jettisoned, but the first stage is recovered for re-use, by releasing a cluster of parachutes after its separation.

It is envisaged that a crew of two or three men could be carried. The mass finally returned to the Earth would be about 8,000 lb. Inertial guidance would be employed for the initial phase from launch to Earth-escape, mid-course guidance into a lunar impact trajectory would be by Earth-based radio, and lunar landing would involve vehicle-contained guidance (lunar-based radio beacons might be used). The same sequence of inertial, radio and vehicle-contained guidance would be used for the return voyage. The pilot would also be able to make optical sightings during the trips and would be able to overide automatic systems except during the inertial guidance stages. Launching would probably be from a Pacific island in the equatorial region.

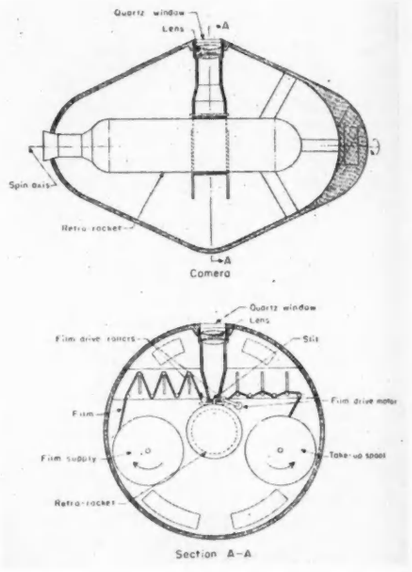
Fig. 1 (right) Schematic drawing of spinning panoramic camera.

Fig. 2 (below) Typical trajectory of lunar photographic vehicle.



Although Mr. Rosen is strongly in favour of a direct-flight vehicle of the Nova type, discussion with American rocket engineers indicates that opinion is veering in favour of using orbital techniques for the lunar trip—refuelling or assembly of the lunar vehicle in a satellite orbit out in space. If this is done the launching vehicle will probably be the Saturn, a four-stage rocket 200 ft in height and weighing 1,160,000 lb at take-off. This is now under construction and will undergo its first flight trials towards the end of 1961. The first stage is a cluster of eight 187,500 lb thrust engines. Saturn will eventually be produced in considerable quantity for use in space operations.

Manned flight to the moon will be preceded by observation from unmanned probes. Merton E. Davies of the Rand Corporation discussed lunar exploration by photography from a space vehicle. The film would be returned to earth in a recoverable capsule. The launching vehicle would have an Atlas or Titan ICBM as first-stage booster and would be able to place a payload of a few hundreds of pounds near the moon. The solid rockets used for later stages would be spin-stabilised, as was done with the Pioneer I and III probes, and a panoramic camera (Fig. 1) not subject to image smearing under these conditions has been designed. The



spin would be used to perform the scanning of the lunar surface, and the film would be moved past a slit at a rate such that the image of the surface did not move relative to the film. The package would be able to sense its spin rate and distance from the ground, would be pressurised and fitted with means to control temperature and humidity near the lenses and film. The pictures obtained about 3,000 miles above the lunar surface would be superior to those obtained by terrestrial telescopes or by television cameras of the type used in the Pioneers.

A figure-of-eight orbit would be used (Fig. 2). The recoverable capsule would have a retrorocket situated along its spin axis and be coated with an ablative material. It is most likely to land in the ocean at a point predictable to within a few hundred miles.

Under the recent US-UK agreement, British-designed satellite instrumentation is to be placed in orbit by the four-stage American rocket, Scout. This is an all-solid propellent vehicle. Mr. H. L. Thackwell, Jnr. (senior vice-president of the Grand Central Rocket Co.) has surveyed the application of solid propellents in spaceflight and suggested an alternative all-solid design.

Solid propellent rocket motors have already been used for the terminal stages of the successful US space vehicles Farside, Explorer, Vanguard and Pioneer, as well as in many military missiles. Their advantages in comparison with liquid propellent rockets are lower cost, greater reliability, rapid development of new designs, ready adaptability to spin stabilisation, good storage characteristics and instant readiness for use. Mr. Thackwell discussed these advantages in detail, but omitted to state the case in favour of liquid propellents. His company has made preliminary design calculations for a simple three-stage, all-solid vehicle which they claim would cost considerably less than the $500,000 figure for the Scout.

The suggested vehicle has been termed Envoy, and would be capable of sending a 50 lb payload

to the moon or placing a 230 lb payload in a 300 mile orbit. It would weigh 17,000 lb, be only 37·8 ft high, and employ conventional propellents in all three motors. The advantages claimed over the Scout would be obtained by using motors especially designed for Envoy's specific task, instead of being composed of existing motors designed originally for other purposes. If a high-altitute second-stage motor were used in place of the booster, Envoy could be launched from a jet aircraft and would then be able to put 430 lb into a 300 mile orbit or 185 lb on the moon.

With the increasing use of instrumented satellites we are learning much about conditions in space. However, there may be undiscovered environmental effects which will affect man. The introduction of animal life into space should uncover all the major effects and give a high probability that there are no minor ones. R. P. Haviland of the US General Electric Company's missile and space vehicle department, reviewed the need for biological satellites and suggested three different vehicles for experiments of varying complexity. Since some of the effects which may be encountered may be cumulative, the biological satellite programme should include both initial short-term flights, and later long-term flights lasting from two to eight weeks.

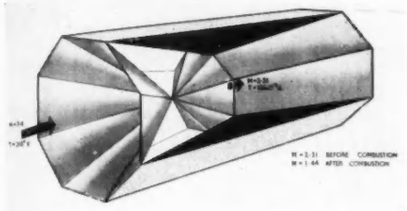
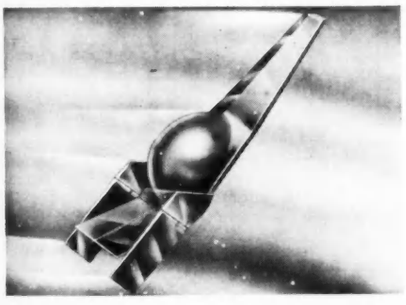


Fig. 3 Shock waves in proposed compression ignition ramjet (Sir W. G. Armstrong-Whitworth Aircraft Ltd.).



Three classes of subjects are recommended. Long-term exposure to radiation would first be conducted with simple subjects (probably the fruit fly). Mice or rats would be used for investigating the effect of radiation on mammals and their long-term adaptability to zero gravity. Tailless primates (such as the Rhesus monkey and chimpanzee) would be used for further studies of this type, including an investigation of long-term effects of zero-*g* on muscle tone, motor response, and so on, and the extent and duration of the relearning process on return to normal *g* conditions. These larger animals would also be used for proof test of equipment designed for manned operation.

Most of the studies to be conducted involve freedom of motion of the subject or long duration, or both, and will thus rule out direct instrumentation of the subject (for example, insertion of electrocardiograph terminals). Indirect measurement techniques will therefore have to be developed. Some of the possible measurements are outlined by Mr. Haviland (oxygen consumption, acoustic noise generation, reaction force on cabin supports, remote measurement of subject temperature, and other parameters), but there is a fertile field for instrument manufacturers to exercise their ingenuity.

Biological satellites will also have to be provided with equipment for support of life for several weeks, but this period is not long enough for it to be worthwhile to attempt closed-cycle operation. Protection against take-off acceleration, re-entry conditions and landing are also discussed.

Commonwealth Symposium

At the commonwealth Spaceflight Symposium, Dr. W. F. Hilton, chief aerodynamicist of Sir W. G. Armstrong Whitworth Aircraft Limited, described a proposed new type of engine expected to have a fuel economy superior to the rocket at Mach numbers between 5 and 10. It is suitable for propulsion in the upper atmosphere and might assist in the propulsion of ballistic missiles or serve as the middle stage of three-stage space vehicles.

The basic principle of the engine is the use of shock heating to produce spontaneous ignition of fuel-air mixtures at supersonic speeds. The proposed intake would be octagonal and would compress the air to a pressure 315 times ambient, causing it to heat up to 1,000° C. The minimum efficient size would be about 32 ft long by 4 ft wide, and the theoretical thermal efficiency would be about 65·3 per cent. A diagram showing shock waves in a proposed compression ignition ramjet appears in Fig. 3.

Mr. O. H. Wyatt of the Hawker Siddeley Nuclear Power Company Limited discussed nuclear-propelled rockets; with hydrogen as working fluid, they were shown to be as good as or better than future chemical rockets. With ammonia, they proved to be intermediate between current and future chemical rockets. The minimum all-up weights of nuclear rockets with graphite-moderated thermal reactors operating at 2,500° C and a maximum propellent temperature of 2,000° C would range from about 100 tons for plutonium fuel and hydrogen to 1,300 tons for uranium and ammonia ; the corresponding thrusts would be respectively 280 and 2,950 tons.

A satellite capable of getting a man into space and back again has been under consideration by a team of scientists at Armstrong Whitworth's; progress so far was reported by the company's technical director, Mr. H. R. Watson. As this work is a purely private venture, no detailed designs have been prepared, but tunnel tests have been made on models with the aerodynamic shape selected. An initial scheme for a one-man space vehicle is illustrated in Fig. 4.

In a later scheme the two-men crew would be inside a cylindrical capsule within the space vehicle, which would be of delta planform with a flat lower surface and an upper portion of pyramid type (Fig. 5). It would be provided with two fins and with retrorockets for braking during re-entry. Its total weight with crew, fuel, power supplies, etc., would be nearly two tons, and the wing loading would be about 12·4 lb per sq. ft. In emergency, the rear face of the pyramid could be jettisoned to allow the capsule to descend by parachute.

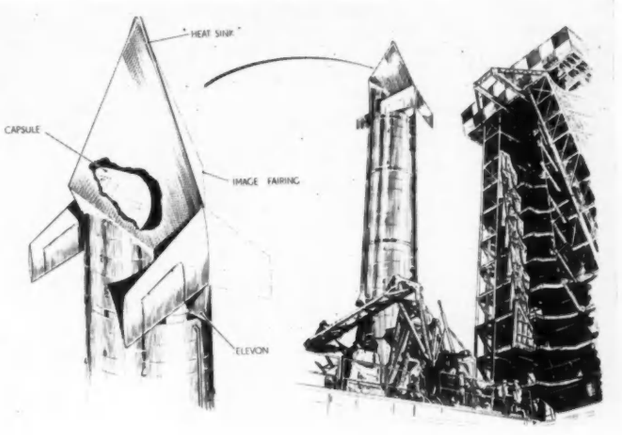
Two of these pyramid-shaped vehicles mounted base-to-base would be launched on top of a 100 ft high three-stage rocket weighing 150 tons. One of the pyramids would be the actual satellite and re-entry vehicle containing the pressurised capsule with crew, the other would be an image fairing to give a symmetrical aerodynamic shape to the nose during launching and would carry propellents. The arrangement is shown in Fig. 6.

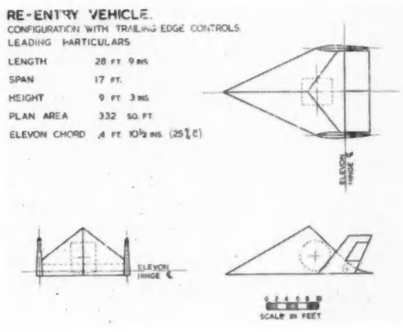
The span of the pyramid satellite would be 18 ft. It is proposed that a model with a 7 ft span should be tested on top of a Black Knight and Blue Streak combination. The two-ton manned satellite would be put in an elliptical orbit with apogee of 700 and perigee of 80 miles, travel round the Earth four times, and then begin its descent as a result of a burst on its retro-rockets at the 700-mile apogee. An expenditure of 17 lb propellents would be sufficient to reduce its perigee to 65 miles—the fringe of the atmosphere. It would then be flown with its nose well up to make use of the high drag charactristic of the delta planform, while ensuring good dissipation of heat. The re-entry speed of 18,000 m.p.h. would fall over a period of 35 minutes to 80 m.p.h. at landing. The whole flight would occupy about 6¾ hour.

Fig. 4 (left) Initial scheme for space vehicle designed to carry a single pilot in a semi-elliptical compartment; capable of escape and partially controlled glide after re-entry.

Fig. 5 (below) Sketch of currently proposed re-entry vehicle with pyramid upper portion, showing trailing edge controls.

Fig. 6 (right) Re-entry vehicle mounted on third-stage of launching rocket. An image vehicle is arranged to provide symmetry.





Some of the problems posed in landing an instrumented package on the Moon were examined by D. S. Carton of the College of Aeronautics. His paper also gives a scaling procedure for vehicles and propulsion systems, together with 22 sets of scaling constants for one solid and six liquid propellents.

One of the most interesting papers at the Symposium was Mr. G. K. C. Pardoe's discussion of various proposals for the combination of Blue Streak and Black Knight rockets into a satellite launching vehicle, but that project could be so readily accomplished that it is perhaps best dealt with in the second article.

Departures in Gas Cooling

It may be argued that the traditional position of the horse before the cart determined the location of the automobile engine for some 30 years. In nuclear engineering the state of flux is such that tradition is not allowed to dominate design. Yet there are some who suggest that tradition has already, after only about 10 years of practice, begun to affect the designers' thinking, and it is refreshing to be reminded of new approaches. Mr. Winnett Boyd, who gave his name to the Daniels-Boyd nuclear steam generator, is of the opinion that the need for canning the uranium fuel of the first plutonium producing piles, which were cooled by river water or atmospheric air, established certain boundaries beyond which designers are only now beginning to venture.

Containment Theory Revised

The need to prevent the escape of active materials from a reactor under the most severe fault conditions has resulted in the practice of double, and in some cases triple, containment. Canning of the fuel is now accepted as the primary safeguard even though it is realised that this is not the only, and may not be the best, solution. Fuel canning has many attractive features and no doubt it is a logical measure: the active matter is confined to the smallest volume, and the possibility of discharging the fuel before a catastrophic rupture ensures that the reactor will not be contaminated. Since the primary coolant circuit stays relatively inactive, it is possible to repair the heat exchangers and gas circulators without undue difficulty.

Cost of Convenience

The very special requirements imposed on the canning materials lead to limitations of the reactor performance which might be regarded as the price of operating convenience. The limitations arise from two different consequences of using canned fuel, and hence operate on different aspects of reactor performance. The temperature range in which the acceptable canning materials are structurally useful severely limits the maximum cycle temperature of the prime mover, particularly of gas-cooled reactors. A great deal of ingenuity has gone into the development of the steam cycles used with the British power reactors to bring their efficiency into an acceptable range. (See Atomic Review, 3 October, 1958.) A significant improvement in steam conditions would of course open entirely new fields of development, leading to reduced capital costs. Equally important is the effect of fission products on the possible irradiation life of clad fuel elements. Cladding prevents the continuous removal of gaseous fission products (in fact, that is its purpose), the accumulation of which affects both the structural and nuclear properties of the fuel: it leads to bulging of the fuel can and the nuclear phenomenon of xenon-poisoning. The practical irradiation life of canned fuel elements is limited at present to about 4,000 MWD per tonne, which is a determining quantity in the cost of the fuel. Any increase in irradiation life would reduce the fuel costs. The decision to contain active material with the fuel affects both the capital and the running costs of a station.

Active Gas Circuit

If canning is abandoned, the situation changes radically, and a new set of limitations circumscribe the reactor's performance. Although the fuel temperature, if ceramic fuel is used, may be raised to 1,800° C, the absence of the metallic fins usually incorporated in the fuel cans impedes heat transfer. This may be counteracted by reducing the size of the individual fuel elements, or by increasing the density of the gaseous coolant, or by increasing the rate of coolant circulation. Each of these apparent solutions carries its own limitations. Similarly, the irradiation life of the fuel elements, instead of being limited by the accumulation of fission products, is now limited by the mechanical properties of the support material (usually graphite), under severe irradiation. Finally, since the entire primary coolant circuit becomes radioactive, the total output of the reactor is limited by the expense of heavy shielding and containment not only for the reactor core and pressure vessel, but for the gas ducts and heat exchangers as well.

World Interest in High Temperature Systems

The problems associated with high-temperature reactors are now being studied in many countries, and it may be expected that renewed diversification will result from this multiplicity of effort. On 12 September, 1958, ENGINEERING described in detail (p. 336) the British high-temperature reactor now the concern of project Dragon; on 3 April and 29 May preliminary data on the Canadian Daniels-Boyd reactor concept were published in Atomic Review, and similar work was reported from the Soviet Union. American high-temperature gas-cooled reactor projects were discussed on 17 October, 1958, and 16 January, 1959. Description of a proposal put forward by the Swiss-German consortium of Brown, Boveri—Krupp; further details of the Daniels-Boyd reactor; and news of a 40 MW(e) high-temperature reactor from America appear below.

Pebble-Bed Reactor

Fuel-Moderator Pellets

In some respects the reactor proposed by the Brown, Boveri—Krupp consortium is remarkably similar to a coal fired furnace (Fig. 1). Fuel elements (Fig. 2) consist of graphite pellets sealed with bonded graphite plugs oriented to ensure that the extrusion directions in the plug and pellet coincide. The fuel is highly enriched uranium monocarbide (20 per cent enrichment is foreseen) mixed with graphite to reduce the power density to acceptable levels. Other identical pellets are filled with thorium carbide as fertile material. The spherical shape was chosen to increase the surface to volume ratio of the elements without reducing their structural strength. Tests show that the pellets can withstand the repeated shock of dropping from a height of 12 ft on to a bed of similar pellets.

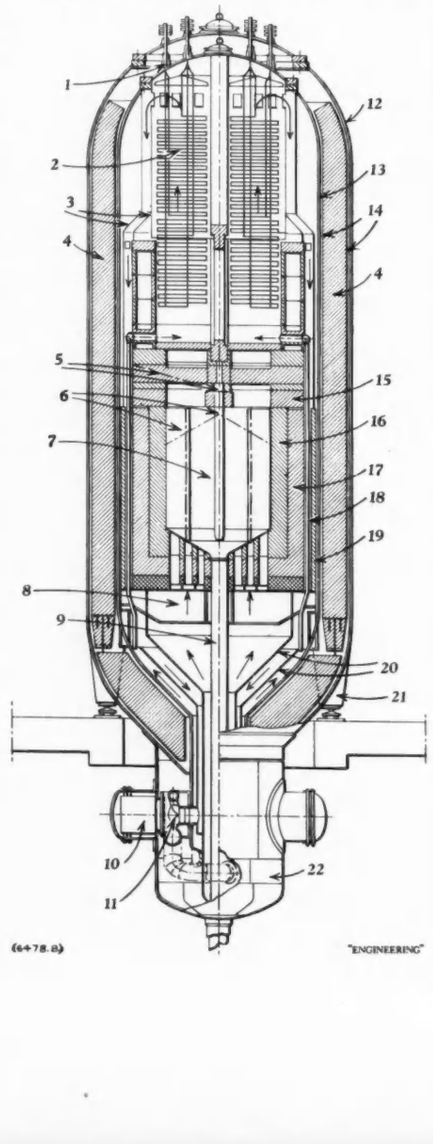


Fig. 1 (left) Core assembly and primary circuit of the Brown, Boveri—Krupp pebble-bed reactor.

1. Steam connections
2. Heat exchanger
3. Gas duct
4. Biological shield
5. Fuel supply
6. Shut-down rod channel
7. Core
8. Support grid
9. Fuel discharge
10. Gas circulator drive
11. Gas circulator
12. Secondary containment
13. Primary containment
14. Inert gas filled gap
15. Carbon bridge
16. Reflector
17. Carbon mantle
18. Gas duct
19. Thermal shield
20. Gas duct
21. Support leg
22. Gas circulator dome

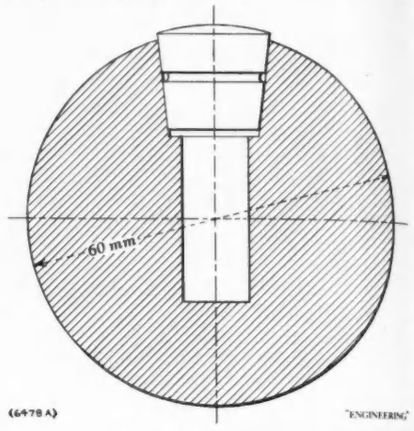


Fig. 2 Fuel element of the Brown, Boveri—Krupp pebble-bed reactor.

Fission Product Diffusion

Since the fuel is not contained in a metallic can, a certain diffusion of fission products throughout the reactor is expected. The exact nature and degree of diffusion are not yet known, and a test reactor is projected for diffusion studies. It is expected that fission products forming stable carbides above 1,000° C will be retained inside the fuel elements. It is hoped that the graphite density will be such that only gaseous fission products, xenon and krypton, will escape from the pellets in appreciable quantities. Continuous filtering of the coolant gas stream will prevent serious contamination of the reactor components, in particular the heat exchanger surfaces. Xenon and krypton will be removed by carbon adsorption at 160° C below zero.

Heat Transfer

The maximum planned fuel temperature of 1,500° C is so high that heat transfer by radiation will play an important part. The good heat transfer properties of graphite ensure that the temperature drop through the pellet will not be more than 30° to 60° C, while the pellet size and coolant properties were so chosen that the difference between fuel element surface and average coolant temperature should not exceed 100° C.

Control System

The fuel and fertile elements are fed in a random mixture through a chute to the reactor core. The fuel level in the core determines the power output of the reactor; power level changes are effected by adding or discharging fuel, while control rods are only used for shut-down. Compensation for small reactivity changes, caused for instance by a settlement of the fuel bed, will be achieved through the negative temperature coefficient of the reactor. A 1 per cent change in reactivity is expected to cause a 200° C change in temperature. Since only heat resistant materials will be used in the core, temperature excursions up to 2,000° C can be tolerated.

Reactor Core

Fig. 1 shows a cross-section of the reactor vessel, which contains the entire gas circuit, circulator, heat exchangers and biological shield. The pressure vessel is of double-wall construction, the interspace being filled with non-active gas at a higher than coolant pressure, ensuring that any leakage through the inner shell will be inwards. A third containment vessel, not shown in the drawing, is planned for ultimate safety.

Coolant

The coolant will be a mixture of helium and neon in the natural proportion of 22 to 78 found in air. The high cost of pure helium in Europe precludes its use, while the helium-neon mixture is obtained locally from air-liquefaction processes.

to submerge the pressure vessel, gas ducts and heat exchangers in a tank of chemically pure water. The tank would be formed by lining the concrete biological shield with a thin sheet of steel.

Many Other Advantages

Apart from lowering the vessel wall temperature sufficiently to permit the use of plain carbon steel, submersion has many other important consequences. The design of the pressure vessel is simplified since internal insulation and external cooling ensure a uniform temperature distribution. The presence of water also obviates the need for a steel thermal shield between pressure vessel and biological shield. Hydrostatic pressure testing of the entire gas circuit is possible instead of the more dangerous testing under gas pressure. The possibility of internal water

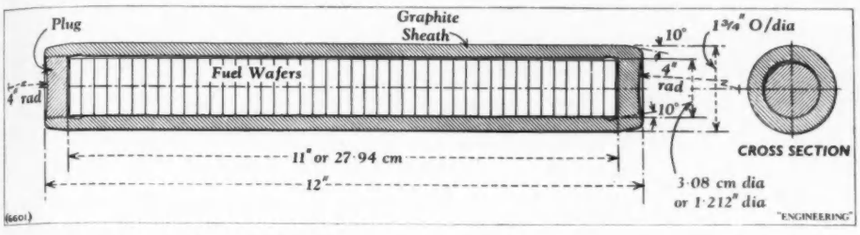


Fig. 3 Fuel element of the Daniels-Boyd reactor.

High Density Graphite and Homogeneous Fuel

Future work will concentrate on the development of high density graphite to assist in fission product containment, and experiments with homogeneous fuel elements that would prevent excessive local temperatures in the uranium-carbide and permit a further increase in the temperature rating of the reactor.

Daniels-Boyd Active Gas Circuit

Low Enrichment Fuel

A unique and ingenious feature of the Daniels-Boyd reactor solves the problem of gas circuit shielding and high temperature pressure vessel design. The reactor, unlike the Brown, Boveri—Krupp proposal, is to operate on natural or slightly enriched uranium monocarbide. As a consequence the physical arrangement and size are very similar to British gas cooled reactors. The chief difference is that the entire gas circuit is radioactive, and that the maximum temperature of the helium coolant, 1,250° F, is well above the useful range of carbon steel.

Submerged Pressure Vessel

The use of high temperature alloys for the construction of the pressure vessel and gas circuit is prohibitively expensive; instead, the designers turned to thermal insulation and cooling. A lining of commercial carbon is proposed for the inside of the pressure vessel and ducts. Carbon, while retaining the good thermal shock resistance of graphite, has only one-tenth of its thermal conductivity and makes a good high temperature insulation. Insulation alone was found to be insufficient, and it is proposed

cooling of the core support structure, the elimination of thermal shock, and increasing the coolant gas pressure are also suggested as consequences of the design.

Fuel Elements

Fig. 3 shows the proposed Daniels-Boyd fuel element. Horizontal channels in the reactor receive the elements which will be cooled by a vertical gas stream. An interesting feature of the design is the method of supporting the brittle fuel wafers and the elements themselves. The wafers rest loosely in a circular sleeve in order to allow for differential expansion. If the wafers were circular, only poor thermal contact would be obtained due to the difference in radii. Contact over 120° is obtained by giving the wafers a periphery that follows three circular arcs, each with the same radius as the sleeve, but having different centres. It is estimated that owing to the good thermal contact, 75 per cent of the heat will be transferred through the lower half of the assembly and only 25 per cent will go upwards. A similar arrangement is used in the graphite channels to support the fuel elements.

Pressure Tube Gas-Cooled Reactor

Improved Efficiency Through Gas Cooling

A synthesis of British and Canadian reactor experience is proposed by the General Nuclear Engineering Corporation in their design of a gas-cooled heavy-water-moderated pressure-tube reactor. The aim of gas cooling is to improve the steam-cycle efficiency by raising the primary coolant outlet temperature. Uranium oxide fuel is proposed, and, departing from American practice, reactor materials were chosen to eliminate the need for enrichment. Fig. 4 shows sections of the core. The light water shield is interposed between the moderator tank and the tube headers to permit maintenance of the headers immediately following reactor shut-down.

Insulated Pressure Tubes

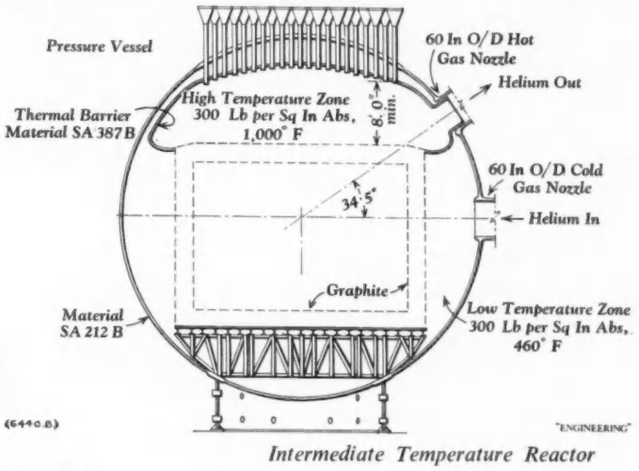
In order to prevent excessive heat transfer between coolant and moderator, it is necessary to insulate the pressure tubes. Two layers of ceramic insulation, separated by a stagnant gas layer, perform this function. It is estimated that the total heat loss from gas to moderator will be 2·8 MW.

Core Parameters

The following is a brief summary of the more important core parameters.

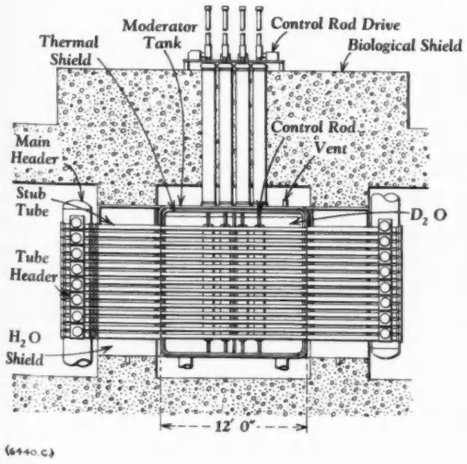
Fuel inventory	17·4 short tons
Insulating material	ceramic
Lattice pitch	8 in
Pressure-tube material	Zr-2
Pressure-tube diameter	4·75 in
Number of pressure tubes	178
Length and diameter of core	12 ft by 10 ft
Moderator inventory	44·5 short tons
Number of control blades	24
Width of control blades	10 in
Pressure in reactor tank	15 lb per sq. in
Average moderator temperature	217° F (100° C)
Average coolant temperature	750° F (400° C)

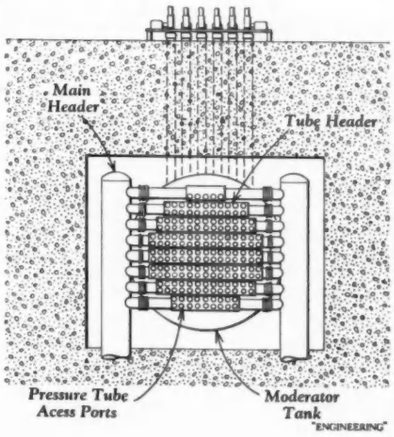
Fig. 5 (right) Pressure vessel of the ORNL intermediate temperature reactor.


Pressure Vessel
60 In O/D Hot Gas Nozzle
Helium Out
Thermal Barrier Material SA 387 B
High Temperature Zone 300 Lb per Sq In Abs, 1,000° F
8·0" min.
60 In O/D Cold Gas Nozzle
34·5°
Helium In
Graphite
Material SA 212 B
Low Temperature Zone 300 Lb per Sq In Abs, 460° F
(6440.B)
"ENGINEERING"

Intermediate Temperature Reactor

Fig. 4 (below) Section through the gas-cooled heavy-water moderated high-temperature reactor.





Conventional Layout

The intermediate-temperature gas-cooled reactor of the Oak Ridge National Laboratory represents an extrapolation of present British nuclear engineering practice. Enriched uranium oxide fuel, stainless steel cans and helium cooling are the main departures. Improvement in secondary cycle efficiency is achieved by raising the maximum coolant temperature to 1,000° F (538° C). Enrichment permits a significant reduction in the core volume, which in turn permits raising the coolant pressure to 300 lb per sq. in. Fig. 5 shows a section of the pressure vessel, which is remarkably similar to current British reactors in its details. (See Atomic Review 5 September, 1958, and 5 June, 1959, also "Reactor Engineering," by R. P. Kinsey, ENGINEERING, vol. 186, p. 730, 1958).

Fuel Element Clusters

Heat removal from the highly rated enriched fuel core is a problem. The fuel elements consist of clusters of six stainless steel tubes, each 0·75 in diameter, filled with annular uranium oxide slugs.

Core Parameters

A summary of the core parameters is shown below.

Core diameter	30 ft
Active channel length	20 ft
Channel diameter	3·25 in
Lattice pitch	8 in
Number of channels	1,597
Fuel inventory	170 tons
Graphite inventory	1,122 tons
Maximum coolant temperature	1,000° F (538° C)

American High-Temperature Reactor

Power Demonstration Programme

A 40 MW high-temperature reactor will be constructed by the Philadelphia Electric Company and General Dynamics Corporation at Peach Bottom, Pennsylvania under the sponsorship of High Temperature Reactor Development Associates. The plant will be the sixth constructed under the Power Demonstration Programme, being scheduled for completion in 1963, and contracts have now been signed with several United States companies. Philadelphia Electric will be the owners and will provide the site and finance the cost of electrical interconnection with their system. Philadelphia Electric will also undertake to operate the plant for the first five years. General Dynamics will design and supply the nuclear equipment, while the Bechtel Corporation and Westinghouse Electric will be the civil and electrical contractors respectively. (See Atomic Review, 26 December, 1958, and 16 January, 1959, when detailed design data were published.)

Homogeneous Fuel Pellets

The helium cooled reactor will be fuelled with homogeneous carbon compacts containing uranium and thorium. Maximum coolant temperature is expected to be 1,380° F (750° C), permitting the use of 1,000° F, 1,450 lb per sq. in steam in the turbine cycle.

Other Approaches

GEC Quarts in a Pint Pot

Three land-based versions of the General Electric Company's gas-cooled ship reactor are currently being designed. It is anticipated that the details of these designs will be published in November. As reported in Atomic Review last 15 May, when the seven Galbraith ship reactor systems were described, the GEC design occupies roughly the same space as the charge-discharge machines in the same company's Hunterston nuclear power station. The small power reactors, which will employ uranium dioxide fuel and stainless steel canning, require an enrichment in the region of 2·5 per cent. On the other hand, can temperatures of 650° C are permissible, giving a heat rating of 225 kW per cu. ft of core—a figure several times higher than would be possible in reactors using beryllium canning, which would be preferred for neutron economy reasons. Fuel costs, with American enriched uranium processed in this country, are said to be 0·25*d* per kWh. The small stations are likely to range in capacity from 40 to 70 MW. For a 70 MW station it is estimated that the reactor, steam generators, containment and supporting structure would cost about £2·5 million, the turbines £2 million (shipped), the civil work about £2 million, and the initial fuel charge £900,000, making a total of about £7½ million and an approximate capital cost of £100 per installed kW.

Plutonium Enrichment

With burnup in the region of 3,000 to 4,000 MWD per tonne, as expected in the first large gas-cooled power stations, there is likely to be a high proportion of plutonium 240 in the spent fuel. This dilution of the fissile plutonium isotopes will make the plutonium produced in these reactors suitable for use as enrichment only in advantageous conditions, as when neutron economy is reasonably good. The situation will improve as higher burnup is achieved.

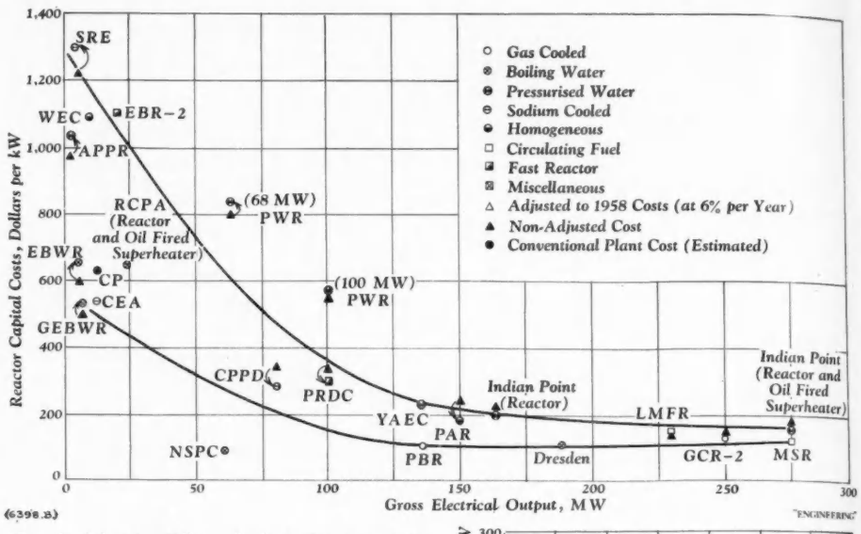


Fig. 6 (above) Effect of plant size on reactor capital cost (excluding conventional plant).

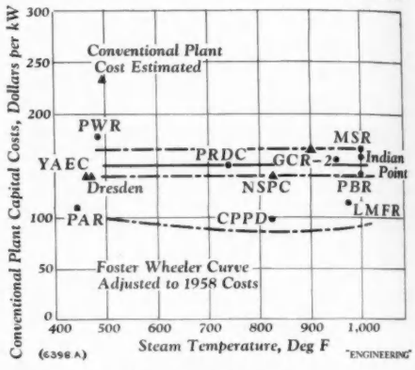


Fig. 7 (right) Effect of steam conditions on conventional plant capital costs; all plants shown reduced to a common base of 100 MW.

Reduced Costs Through Better Engineering

A study of American power plants of all types, both nuclear and conventional, indicates that better engineering will play the dominant rôle in achieving low cost power in the future. The indications are that other methods—increased output or improved nuclear and steam cycles—may have little influence on the costs. The curve of Fig. 6 shows the variation of reactor capital cost with output for all types of practical reactor. Although the scatter is considerable, the implications are clear: in the interesting range of output—150 MW(e) and upwards—the difference between reactor types is small, and there is little to be gained from increased size. A second study, illustrated in Fig. 7, shows that improved steam conditions have little effect on the capital cost of conventional plant associated with a station.

Smaller Pressure Vessels

The trend is towards reduced size in pressure vessels for gas-cooled graphite-moderated reactors. A comparison is shown in Fig. 8. The 61 ft diameter Trawsfynydd sphere was achieved by increasing the operating pressure to 240 lb per sq. in (2½ times that of Calder Hall), and the plate thickness to 3½ in (Atomic Review, 21 Aug. '59). In America the trend is similar, although the method differs. Any significant reduction beyond that achieved at Trawsfynydd necessitates increased core heat rating, which implies enrichment. 400 lb per sq. in operating pressure, with a pressure-vessel plate thickness of 4 in, accounts for the small vessel size proposed by Kaiser Engineers for their helium cooled KE-ACF-Enr reactor. The ability to weld and radiograph in the field 4 in thick steel plate is postulated. Helium cooling at 300 lb per sq. in pressure is used in the GCR-2 reactor developed by the Oak Ridge National Laboratory (Atomic Review, 5 June '59). The pressure-vessel plate thickness is limited to 3 in in order to utilise existing field erection experience.

References to Gas-Cooled Reactors

The following is a list of articles dealing with aspects of gas cooled reactors published in ENGINEERING: Reactor Engineering (R. P. Kinsey), 5 Dec. '58; Power Reactors (G. W. K. Ford), 28 Nov. '58; British Reactor of the Future (HTGR) (L. R. Shepherd *et al.*), 12 Sept. '58; Calder Hall, 2 Nov. '56, 12 Oct. '56, 5 Oct. '56. Further references to gas cooled reactors in Atomic Review are the following.

Trawsfynydd nuclear power station 21 Aug. '59; Gas cooling goes abroad 5 June '59; Distinguishing features of Chapelcross 29 May and 3 April '59; Ship propulsion 15 May '59; GEC reactor for Japan 6 March '59; Dragon Project 20 Feb. '59; Daniels-Boyd Nuclear Steam Generator 27 Feb. '59 and 26 Dec. '58; American high temperature reactor 16 Jan. '59; Latina power station 28 Nov. '58; Aircraft propulsion 7 Nov. '58; Gas-cooled reactor conference in USA 17 Oct. '58; Charging on load at Bradwell 17 Oct. '58; Steam cycles for advanced reactors 3 Oct. '58; Turret gas cooled reactor concept 3 Oct. '58; EDF1 and EDF2 (France) 5 Sept. '58; Pressure vessels 6 June '58; Heavy water moderated gas cooled reactor 28 March '58; GEC high temperature gas-cooled reactor 21 March '58; Hinkley Point station 14 March '58; Temperature coefficient of gas-cooled reactors 7 March '58; Reactors in flight 28 Feb. '58; Gas cooled marine reactor 7 Feb. '58; Advanced gas-cooled reactors 10 Jan. '58; Windscale 15 Nov. '57; Design of graphite moderators 15 Nov. '57; Berkeley power station 18 Nov. '57; Hinkley Point power station 27 Sept. '57, 20 Sept. '57; Concrete pressure vessel 16 Aug. '57; Hunterston power station 26 July '57; Bradwell power station 31 May '57; Development after Calder Hall 22 March '57; Bradwell reactor design 22 Feb. '57; Details of Berkeley station 1 Feb. '57; Berkeley, Bradwell and Hunterston 28 and 21 Dec. '56.

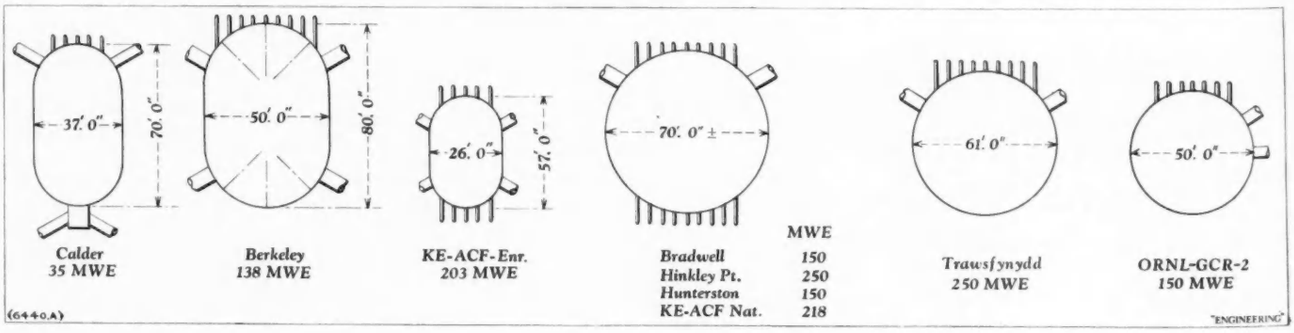
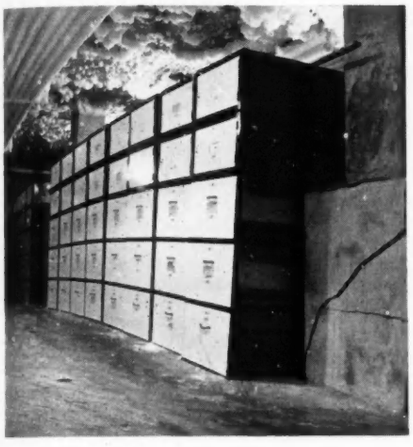


Fig. 8 Pressure vessels for gas-cooled reactors.

FROST ACTION BELOW COLD STORAGE BUILDINGS

In recent years extensive structural damage to cold storage buildings by differential movements of the underlying ground have been reported both in this country and elsewhere. In Canada several cases have been brought to the attention of the Division of Building Research in Ottawa through inquiries about possible remedial measures. To meet these requests a study of the problem was undertaken by the division.

The structural failures that were observed were a consequence of a process occurring in the soil known as frost action, a subject already being investigated by the division. Frost action is a direct result of freezing of the ground. During the freezing process, a suction is developed at the plane between frozen and unfrozen soil and the suction is capable of drawing water to this plane where it freezes. If therefore a supply of water is available there will be a considerable accumulation of ice in the soil, which results in an upward movement of the ground surface. The process occurs most readily in fine-grained soils which are said to be highly frost susceptible. Although there is no reliable criterion of frost susceptibility, well-drained sand and gravels are known to be relatively free from frost action. In the Ottawa area, for example, the Leda clay and a relatively high water table form a definitely frost-susceptible combination.



Interior of a refrigerated locker room in Ontario. Deep freezing of the surrounding soil can cause bad differential settlements.

The effect of frost action on highways is a commonly observed phenomenon in Canada and is a result of the winter freeze-up. In contrast to this seasonal process, a cold storage structure of slab-on-soil construction continually subjects the soil to subfreezing temperatures which can lead to the formation of large thicknesses of ice. In a dramatic example at Cornwall, Ontario, which has been under study by the division, during a period of about three years a differential movement of the floor slab of over 1 ft occurred. The illustration is an interior view of this locker plant.

Simple heat transfer calculations were employed for the preliminary analysis. The results of the analysis confirmed the fact that a structure of appreciable size of slab-on-soil construction, continually maintained at a sub-zero temperature, will eventually cause freezing of the soil beneath a considerable depth. Consequently, if such a structure is situated on a frost-susceptible soil with water present, frost heave difficulties will be encountered. Furthermore, attempts to prevent soil freezing by increased thickness of floor insulation are definitely not practical, for purely economic reasons, since abnormally large thicknesses of insulation would be required.

There are several possible methods of eliminating potential frost action damage. Elevated floors to isolate the floor from the ground offer one possibility, but this solution can be costly. Simple calculations have indicated that the introduction of modest quantities of heat beneath the floor of such a building will be adequate to eliminate the danger, and the procedure is judged to be economically practical. The study made by the division has also indicated that the circulation of outside air during the summer months, through a duct system beneath the floor would probably furnish adequate heat to prevent soil freezing to any substantial depth.

The fact that a structure of a slab-on-soil construction, operating continuously at sub-zero temperatures, will cause freezing of the soil beneath, leads to the conclusion that structural damage of such a building by frost action is a probability if the soil is at all frost susceptible. To avoid serious economic losses, potential damage by frost action should be adequately considered in the design of the building. For part of the year at least warm summer air will be an adequate and cheap source of heat for the reduction of frost action damage, though this could lead to an increase in refrigeration costs.

The division has published three papers dealing with the investigation just described; inquiries for copies should be addressed to the Publications Section, Division of Building Research, National Research Council, Ottawa, Canada.

WELLINGTON'S NEW AIRPORT IS WITHIN THE CITY

The new Rongotai airport of Wellington, the capital of New Zealand, has been built within the city limits—an ideal that few capitals can attain. It is only 15 minutes, drive from the main post office but Viscount airliners can operate from it. It has brought Auckland, 400 miles away, to within 80 minutes travelling time, and a 40 miles road journey to the former airport at Paraparapaumu has now been eliminated.

Land has been reclaimed from the sea to create a nearly-flat isthmus across which the single-runway airport has been built. Construction work has been undertaken by the New Zealand Ministry of Works in conjunction with the City Council, the council being responsible for the provision of internal and external services such as roads, stormwater drainage, terminal buildings and associated facilities.

A formation that is 6,150 ft long by 725 ft wide has been prepared for the airport. Within that area is the single paved runway 150 ft wide and 5,350 ft long, plus concrete stopways 250 ft long at the northern end and 150 ft at the southern. A 60 ft wide taxiway runs parallel to the runway on the east side and provides a connecting route between the runway and the terminal area. The paved area additional to the taxiway and runway totals 22 acres. All the pavements are of a "flexible" construction, using bitumen, with the exception of the stopways and the aircraft parking hardstandings in the terminal areas, which are all of concrete.

Location of the new runway is across a low lying neck of land stretching from the ocean beach of Lyall Bay to the harbour arm of Evans Bay and known as Rongotai. Aircraft will land and take-off along an open valley between two 500 to 600 ft ridges. Close by, the city is hemmed in against the sea by a mountain range with 2,000 ft peaks. The siting of the runway gives over-water approaches from both ends, but they are of only limited width because of the nearby hills. Conventional approach lighting is impracticable because of the depth of the water.

Land has been reclaimed from the sea at both ends of the runway—indeed, more than one-third of the runway is on made land. A considerable hill on the line of the runway had to be removed and some nearby hills "shaved back" to give lateral clearance to conform with the requirements of the International Civil Aviation Organisation. The earthworks totalled 4 million cu. yd. In addition 180 houses, three factories and an old hangar from a much earlier aerodrome had to be removed. The final surface of the new runway is 38 ft above sea level at one end and 19 ft at the other.

In Lyall Bay, at the southern end of the runway an 850 ft breakwater had to be built, requiring 3,250 concrete blocks and tetrapods. The wall protecting the south-west corner of the runway was built behind and above 1,500 tons of sheet piling. Several acres were also reclaimed in Evans Bay to the north and on this were re-erected most of the 180 houses, many of which were transported to their new sites by road, either whole or in sections.

Rongotai Airport, built within the city area of Wellington, New Zealand. The photograph has been taken from an aircraft approaching from the south. About one-third of the runway is built on reclaimed land.

Four concrete buildings to house the surveillance radar and radio stations have been erected 4½ miles away on Mt. Hawkins at an altitude of 1,650 ft and in an extremely exposed position. It is the first time that surveillance radar equipment (SRE) and precision approach radar (PAR) have been installed in New Zealand. The SRE is a Marconi set (S 246 A) operating on the

high power of 500 kW. It uses a 50 cm wavelength thus compromising between accurate pinpointing of aircraft positions and freedom from clutter by heavy rain. The aerial system is a tubular steel structure 55 ft long by 16 ft high, strengthened to withstand the high winds experienced on Mt. Hawkins, and rotated at 10 r.m.p. by two 35 h.p. electric motors; the rotation speed is cut to 5 r.p.m. when the wind exceeds 70 m.p.h.

Information from the SRE is relayed to the Wellington Regional Air Traffic Control (giving the position of all aircraft in the air within a radius of 100 miles) and to Wellington Airport control tower (aircraft within 30 miles).

The PAR (made by Standard Telephones and Cables Limited) enables the control tower to bring aircraft in from about 10 miles to within ¼ mile of touch-down, or even closer in an emergency. Normally, radar guidance ends when the let-down is completed to within 75 ft of the runway level, when the landing can be made visually. This equipment has enabled the conventional approach lighting to be omitted, even if the deep-sea approaches had not made it impracticable.

All other normal airport aids for pilots have been installed: non-directional radio beacon and distance measuring equipment. There is also the usual array of threshold, runway and taxiway lighting with a dual " no-break " power system, obstruction lights, apron floodlighting and control tower beacon.

Temporarily an existing building has been converted for use as the terminal building but a new hangar has been completed. Later stages of development will see a new terminal building, offices and carparks. The airport began services at the end of July with the departure of two Viscount turbojets, one bound for Auckland to the north, the other for Christchurch to the south.

HYDROELECTRIC PROJECT IN ALBERTA

The Brazeau River hydroelectric power site is located on a big bend of the river, 96 miles southwest of Edmonton in Canada. The immediate plans of Calgary Power Limited, who hold the development rights, involve installing 200,000 h.p. of generating equipment there, though it is thought that the ultimate capacity is at least four times this amount.

The initial development of the big bend site will include an earth-filled dam two miles long; a reservoir in the Brazeau valley containing 900,000 acre-feet of usable storage; a canal to carry water to the power house and an associated pumping station; the power house itself, which will allow for future installation of more generating equipment; and the spillway. A head of 400 ft will be available at the turbines.

This work will take about four years to complete and it is expected that current will first be sent out in the late autumn of 1963. Filling of the reservoir is expected to be complete by the end of the winter of 1964 to 65. The capital required for the initial development of the site will be about $45 million. It is estimated that each additional 200,000 h.p. added to the plant will cost another $10 million, including transmission lines.

Until recently it had not been intended to develop the site before the demand for power had grown sufficiently to justify both the high initial cost and the large peak power potential, which could anyway have been obtained more economically elsewhere. The project is being put in hand, however, because the reservoir will aid industry generally and the release of water during the low winter flow period will relieve a pollution problem along the lower reaches of the river. Ultimately the project will help to open up a whole new area of Alberta that, because of dense forests, was virgin territory until a few years ago.

Tyne Tunnel Approved with Tolls

The approval that the Minister of Transport has just given to the Tyne tunnel project relates to revised plans prepared after a reconsideration of the project by the consultants, Mott, Hay and Anderson of London. The new plans show that the tunnel can be driven through the bedrock (boulder clay, which is likely to be fairly wet) and provide accommodation for the toll booths. The tunnel will have two traffic lanes and be about a mile long; the cost is likely to be £12½ million.

If Parliamentary permission is granted during the next session (it is unlikely to be refused because earlier plans have twice been authorised, in 1946 and 1956) work could start towards the end of 1960; completion of the tunnel and the 4 miles of approach roads is expected to take five or six years.

Railway Testing and Research in India

The annual report (1957-58) of the Railway Testing and Research Centre at Lucknow, India, contains an account of the work being done there on a number of civil engineering problems.

Doubt is expressed that the accuracy of fabrication and erection of bridges is sufficient to enable secondary stresses in members to be countered by induced prestress. Theoretically this is possible but observations are being made on new bridge structures to find to what extent such secondary stresses can be nullified by prestressing.

Much work is also being done on rail stresses, particularly fatigue and concentration of stress at fish-bolt and bond holes. The joint director of research (civil), Mr. W. G. K. Rao, is the author of *Soil Mechanics for Railway Engineers*, just published and available from the Centre at 12*s*.

Other work at the Centre includes investigations into carriage and wagon running, particularly performance tests of different bogie units. A German design has so far been found superior to others tested.

Hydraulics Research at Wallingford

During the past year the Hydraulics Research Station at Wallingford has carried out two special investigations for the London County Council to forecast the probable frequencies of floods and maximum flood levels if proposed channel improvements were made to two tributaries of the Thames. These tests are described in some detail in *Hydraulics Research 1958*, published by DSIR (price 6*s* from HMSO). The tests are typical of those that can be done on relatively small-scale projects to effect a considerable improvement in the completed works for a given expenditure.

Other model investigations carried through concerned the siting of power stations, particularly the cooling water inlet and discharge points. Harbour models include one for the fishing harbour of Eyemouth in Scotland and described in ENGINEERING, 19 Dec. '58, p. 808. Models have also been used to investigate difficulties encountered in hydroelectric power projects. Long-term research on the beach-building properties of different types of groyne continues.

Improved Weatherproofing for Roofs

Trouble has frequently been caused to weatherproofing on roofs, such as bitumen sheeting, by the build-up of water vapour pressure, particularly from insulating concrete screeds. To meet this difficulty the Ruberoid Company, Commonwealth House, New Oxford Street, London, WC1, have produced a new roof covering called Rubervent.

To enable the vapour to get away, and also to permit differential temperature movements in the roof substructure, the first under-layer is coated on the underside with coarse mineral granules. Any blistering of the sheeting due to trapped moisture is thus prevented. Full details of the sheeting, bonding methods and fixing are given in a leaflet entitled " Rubervent" issued by the company.

Fish Pass at Orrin Power Station

The North of Scotland Hydroelectric Board have brought into commercial operation their Orrin power station in Ross-shire. It contains one 18 MW machine operating under a gross head of 728 ft and is expected to have an annual output of 76 million kWh. The catchment area utilised is 54 square miles.

A considerable variation in reservoir level is expected and a Borland fish pass has been built to enable salmon and kelts to pass. The Orrin Falls have also been eased to help the fish in their ascent.

Sheet Piling Order from Suez

About 10,000 tons of sheet steel piling have been ordered by the Suez Canal Authority from the British Steel Piling Company Limited, London. It is to be used for widening the canal over a length of more than 11 miles. The value of the order is about £500,000. The Appleby-Frodingham Steel Company will make the piling at their Scunthorpe Works.

Durability of Glued Wooden Joints

Since 1940 the Forest Products Research Laboratory have been investigating the durability of all types of glues in wooden joints exposed in natural environments. The purpose is to give guidance to users on the efficient use of glues, an efficient glue being one that maintains an adequate bond under the conditions of service that the joint has to withstand. The results obtained to date are summarised in Forest Products Research Bulletin No. 38 issued by DSIR, entitled *The Efficiency of Adhesives for Wood* (price 3*s* from HMSO).

Phenolic and resorcinol resins are shown to be most satisfactory over the range of conditions considered, which is very wide.

Floor Finishes for Factories

The choice of materials available for factory floor finishes, and their cost per square yard, is discussed in a new booklet, No. 3 in the Factory Building Series produced by the Building Research Station (*Floor Finishes for Factories*, HMSO, 1*s* 9*d*).

Costs vary from 9*s* 3*d* per sq. yd for a 1 in Portland cement screed to 54*s* for 2 in of concrete including a ⅜ in terrazzo topping. Pitchmastics start at about 12*s* and an acid-resistant asphalt costs 20*s* per sq. yd. Quarry tiles (1¼ in thick), bedded in various cements are much more expensive, rising to as much as 119*s*; 2 in brick paviors cost about the same as tiles. Prices are also given for coverings and skirtings.

Radiators Made of Concrete

A suggestion for making radiators using concrete comes from Russia. The ducts could be made in a number of ways, including the use of oiled rods or inflated tubing that could be withdrawn after the concrete had set. With dense concrete good mating faces could easily be obtained between adjacent components. Reports suggest that heating panels made in this way will have a surface temperature of 150° F when water at 185° F is circulating.

THERMOELECTRIC POWER

An Investigation of its Possibilities

Part 3 Concluded from page 132, 4 September

By G. W. Wilson, B.Sc., Ph.D., and B. C. Lindley, B.Sc. (Eng.)

Having previously discussed the fundamental principles and engineering design parameters of thermoelectric power generation in Parts 1 and 2, the final part of this article is devoted to a general discussion and an approximate analysis of the economics involved.

General Discussion

Alternating and Direct Current Power Generation

Owing to the necessity, in a thermoelement constructed as depicted in Fig. 13 (Part 2, p. 130), of transferring heat through the electrical insulation, the thickness of the latter must be as small as possible. Since the insulation also has to operate at a high temperature the breakdown voltage of the thin layer will be rather low and it is anticipated that power will be produced at a voltage level in a range up to 500 volts, compared with large turbo-alternators which generate at 11 kV.

There are numerous instances of the application of d.c. on a fairly large scale, such as variable-speed motors, electrolysis, production of aluminium, and copper refining. Some of these involve voltages in the range 12 to 24. Powers of up to a few megawatts are typical. There is thus scope for individual low-voltage high current d.c. installations of appreciable size.

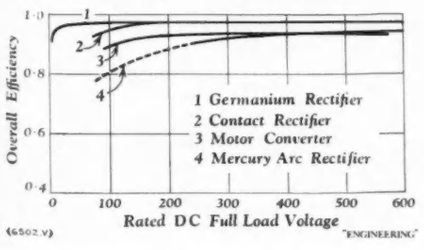
Where it is intended to couple the generator to a grid system, such as might be the case with a nuclear reactor installation of appreciable ouput, the problem arises of transforming the voltage to a high level for transmission, since distribution at such a low voltage would be uneconomic for even very short distances. Inversion to low-voltage a.c. with subsequent step-up to the a.c. transmission voltage would be necessary.

Three methods of inversion appear feasible, not including motor inverters. The first is the standard grid-controlled mercury arc inverter, which suffers from poor efficiency at low voltages, owing to the inherent "arc drop" of 20 to 35 volts. At voltages above 300, however, efficiencies greater than 90 per cent can be achieved. The second is the mechanical contact rectifier[20] which, in modified form, could be used for inversion and has an efficiency of about 97 per cent at input voltages greater than 100 and at very low percentages of full-load current. The third method is the use of semiconductor "trinistor" units which are at present under development for high-current low-voltage applications.[21]

Fig. 21 compares the efficiencies of mercury arc rectifiers, motor converters, contact rectifiers and germanium rectifiers. Efficiencies for inversion may be slightly lower. It may be expected that the trinistor device would have an efficiency at least as good as the germanium rectifier. Reference [21] quotes efficiencies of over 99 per cent.

Thus there appear to be no major disadvantages in the adoption of generators producing low-voltage d.c. Certain direct systems of utilisation are possible and transmission of power can be achieved by inversion to a.c. and subsequent step-up to high voltage, with no appreciable penalty in efficiency.

Fig. 21 Efficiencies of converting plant as a function of rated d.c. full-load voltage.



Applications

A wide range of application appears possible and, since there is no scale effect, thermoelements can be multiplied indefinitely. Provided suitable heating and cooling can be arranged in conjunction with the available resources of heat and cooling water, any size of power station could be constructed, and the choice of thermoelectric or thermionic generators in these conventional applications would rest almost entirely on economic considerations.

Where the primary consideration is of reliability and thus lack of maintenance, or compactness, or low initial cost, numerous applications can be envisaged such as for remote districts and for packaged-power units. It has already been shown that an electrical power output of 20 kW per cu. ft of effective generator matrix is feasible.

Ship propulsion might be attractive, a d.c. supply being very suitable for the main propulsion motors, for cargo-winch motors, and for other auxiliaries. Suggested special applications include the provision of a guaranteed electrical supply for the coolant circulators of a nuclear reactor, a generator for charging the battery of a road vehicle utilising waste heat from the engine exhaust gases, a compact temperature-sensitive control device with appreciable power output, and the exploitation of heat sources such as solar heat, fission product heat and waste heat from reciprocating and gas turbine engines, furnaces and chemical plant.

Economics

There is little information on which to base an economic study, since basic semiconductor thermoelement costs are an uncertain factor. However, it is proposed to derive some approximate figures for a practical system and then to investigate more general economic features by considering only basic parameters, such as temperatures and figure of merit.

The example chosen is that of the organic moderated and cooled reactor system for which data were previously derived. Taking the semiconductor material to be basically bismuth telluride, this is at present available at about £1 per lb and it is assumed that the thermoelectric generator can be built for £2 per lb of semiconductor material, including copper conductors, insulation, cladding, basic construction, headers and auxiliaries. Fig. 22 shows the specific cost of the generator as a function of heat flux, illustrating the necessity of a high value of heat flux.

Choosing an output of 20 MW(e) Fig. 23 shows the capital cost, in arbitrary units, of the reactor system without steam-raising units or turbo-alternators. The costs are derived from the required reactor heat duty and allow for the lower specific cost of larger plant as the thermal efficiency decreases. The total capital cost, with thermoelectric generator, is also shown, as a function of heat flux, giving a minimum of 95 units for a flux of about 11·5 watt per sq. cm. With a turbo-alternator the reactor system, having a thermal efficiency based on electrical power generated, of about 23 per cent, for 20 MW(e) would cost 90 units. Thus the system capital cost with a thermoelectric generator would be a little higher than with a turbo-alternator. This is on account of the low thermal efficiency and illustrates the need for semiconductor materials with a figure of merit greater than about 5×10^{-3}.

Clearly, even if the capital cost of the two systems had been the same, the fuel cost for the thermoelectric system would have been much higher, as would the unit cost of electricity.

The more general appreciation which follows demonstrates the performance requirements of the semiconductor materials.

Consider a reactor system for which the specific cost (based on core heat capacity and not on electrical output) varies only with size and not with operating temperature. The efficiency of a steam cycle, and of thermoelectric generators having thermoelements of material with various figures of merit, is shown in Fig. 24,

Fig. 22 Specific cost of OMR thermoelectric generator as a function of generator heat flux.

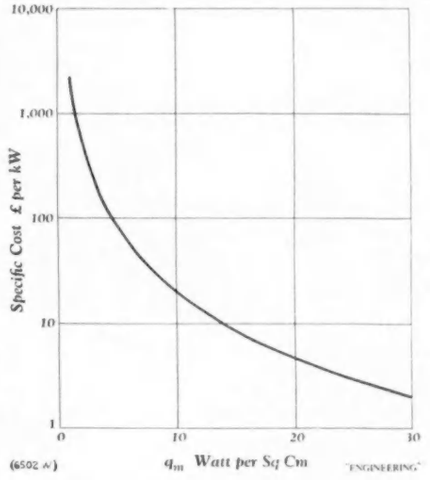
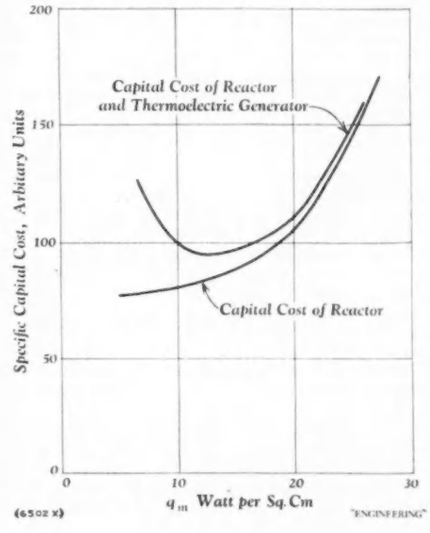


Fig. 23 Capital cost of OMR and OMR thermoelectric generator as a function of generator flux.



as a function of the upper temperature of the cycle. It should be noted that the efficiency is based on electrical power generated and, in the case of thermoelectric generators, is adjusted to allow for a reasonable difference between the cycle upper temperature and the temperature of the hot junctions, for a liquid heat transfer agent. It must be understood that liquids (for example, liquid metals) may not be practicable as heat transfer agents at the highest temperatures considered. If gases are used the efficiencies must be reduced, due to the increased temperature difference between a gas and the hot junctions.

The cost of nuclear fuel is taken to be 0·1*d* per kWh of heat output from the reactor. This is rather a high value and will, if anything, penalise the low-efficiency thermoelectric generator. The cost of nuclear fuel, expressed in this manner, would be about 0·06*d* per kWh for CEGB stations now building. By way of comparison, the cost of coal and fuel oil is about 0·14 to 0·15*d* per kWh.

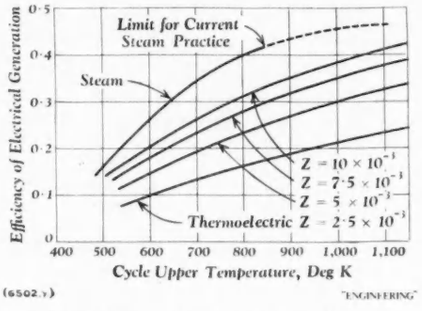


Fig. 24 Efficiency (based on electrical power generated) of steam and thermoelectric power stations, as a function of maximum temperature (reactor coolant outlet) at $T_0 = 300°$ K for thermoelectric generators.

Based on these assumptions the comparative unit cost of power has been derived, for the steam station, and for thermoelectric generation, as a function of the cycle upper temperature, for the same station output. Lacking information at this stage of the cost of the thermoelectric generator, specific costs of £20 and £40 per kilowatt installed are considered. A load factor of 80 per cent is assumed. Fig. 25 shows the result of these calculations. The curves for thermoelectric generation are shown for a specific cost of the generator of £20 per kilowatt. The effect of an increase to £40 per kilowatt is to add a constant 0·08*d* per kWh.

The curves show that, to be competitive with conventional methods of generation, the thermoelectric generator must utilise materials having a figure of merit of the order of 5×10^{-3}. There is a tendency for the thermoelectric generator to show a bigger improvement in the cost of power both at very high temperatures (say, above 1,000° K) and also at very low temperatures (say, below 500° K) where the steam cycle becomes inefficient.

Thus, the indication is that research and development effort should be expended in particular on two classes of semiconductor material. The first are semiconductors which would allow the efficient utilisation of low grade waste heat. Hot junction temperatures of up to about 250° C would be involved, with the achievement of as high a figure of merit as possible. The second are materials capable of very high temperature operation. Maximum cycle temperatures for rotating machinery are in the region of 1,000 to 1,100° K and there seems little prospect of operation at very much higher levels (perhaps up to 1,300° K for highly-rated gas turbines with special materials and cooling methods). Many of the materials capable of withstanding high temperatures, such as refractory oxides and carbides, are too brittle to be incorporated in rotating parts, but could well operate in a static device such as a thermoelectric or thermionic generator. There is some evidence to suggest that the thermoelectric performance of some of these materials could be developed to a sufficiently high level. Other problems, including the choice of good electrical conductors, insulators and structural materials, and thermal stress, are aggravated at high temperatures.

The discussion above is based on economic factors, and other factors may widen the field of application of thermoelectric generators. The advantages of reliability and lack of maintenance, and compactness, could in some circumstances outweigh cost considerations.

Conclusions

It is clear from this survey that thermoelectric and thermionic devices have, at the present, been developed sufficiently to warrant serious consideration as a means of electrical power production. Further improvements in materials and methods of construction can be expected to lead to a performance equivalent in thermal efficiency to present methods of generation, with a reduction in the capital cost of the plant.

The following general conclusions can be drawn:

1. Electrical generation by means of thermoelectric devices is feasible and reasonable thermal efficiencies can be obtained with semiconductor materials having figures of merit greater than 5×10^{-3}. Liquid heat transfer fluids are preferable in the thermoelectric generator.
2. A very approximate analysis of the economics of thermoelectric generation using a nuclear heat source indicates that the method yields electrical power at a cost about equivalent to conventional steam turbo-alternator plant when the semi-conductor material has a figure of merit in the region of 5×10^{-3} if the generator can be built for £20 per kilowatt, and $7·5 \times 10^{-3}$ if the generator costs £40 per kilowatt capacity. There is a tendency for the thermoelectric method to show up more favourably at low temperatures (less than 500° K) and at high temperatures (greater than 1,000° K).
3. The field of application appears to be very wide but the economic and operational advantages in particular systems can only be evaluated after more detailed study.
4. It appears that the high temperature range, say above 1,000° K, of a thermodynamic cycle, can be matched to a thermionic or thermoelectric device. Further development will indicate which method shows up to best advantage, or even if other suggested methods of direct conversion are more attractive.
5. Thermionic devices which are actual nuclear elements are worthy of study; an interesting system is one in which the heat rejected by such a device is then passed to other generating plant, either conventional or thermoelectric.

Acknowledgement

The authors are indebted to the directors of the Hawker Siddeley Nuclear Power Company for permission to publish these articles; the opinions expressed are those of the joint authors.

REFERENCES

[1] L. Pearce, "A Review of Forty Years Development in the Mechanical Engineering Plant for Power Stations," *Proc. I.Mech.E.*, 1940, pp. 305-363, London.
[2] *Central Electricity Report and Accounts*, 1957-58, HMSO, London, 1958.
[3] *Report on Heavy Oil Engine Working Costs and Performance*, Diesel Engineers and Users Association, 1957-58.
[4] M. Barmat, G. M. Anderson, E. W. Bollmeier, "Snap III—Electricity from Radionucleides and Thermoelectric Conversion," *Nucleonics*, pp. 166-177, Vol. 17, 1959.
[5] E. Altenkirch, *Phys. Z.*, p. 920, vol. 12, 1911.
[6] A. F. Joffe, Semiconductor Thermoelements and Thermoelectric Cooling," *Infrosearch*, London, 1957.
[7] M. R. Champeix, "Transformation of Heat into Electrical Energy in Thermionic Phenomena," *Le Vide*, pp. 936-940, vol. 6, 1951.

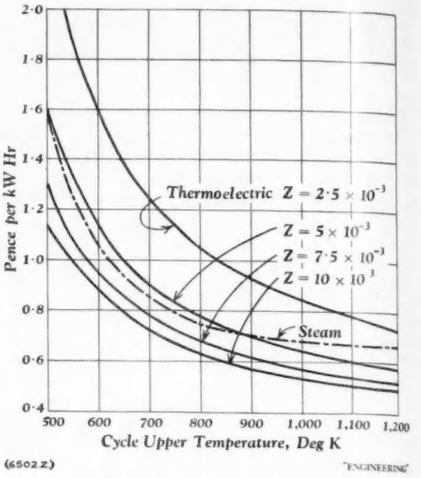


Fig. 25 Unit cost of electrical power generated by steam turbo-alternator and thermoelectric stations as a function of cycle upper temperature. Thermoelectric generator cost £20/kWe. Load factor 80 per cent.

[8] G. N. Hatsopoulos, "The Thermoelectron Engine." Sc.D. Dissertion, M.I.T., Ma., USA, 1956.
[9] H. Moss, "Thermionic Diodes as Energy Converters," *J. Electronics*, pp. 305-322, vol. 2, 1957.
[10] G. N. Hatsopoulos, J. Kaye, "Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine," *Proc. I.R.E.*, pp. 1574-1579, vol. 46, USA, 1958.
[11] G. M. Grover, D. J. Roehling, E. W. Salini, and R. W. Pidd, "Properties of a Thermoelectric Cell," *J. Applied Physics*, pp. 1611-1612, vol. 29, 1958.
[12] K. W. Plessner, *Proc. Phys. Soc.*, p. 671, vol. 64B, 1951.
[13] M. Telkes, "Solar Thermoelectric Generators," *J. Appl. Phys.*, pp. 765-777, vol. 25, 1954.
[14] S. V. Airapetyants, *et al.*, "On the Mobility of Electrons and Holes in Solid Solutions in Lead and Bismuth Tellurides," *Zhur. Tekh. Fiz.*, p. 2167, vol. 27(9), 1957.
[15] D. A. Wright, "Thermoelectric Properties of Bismuth Telluride and Its Alloys," *Nature*, p. 834, vol. 181, 1958.
[16] H. J. Goldsmid, "Electrical Conductivity and Thermoelectric Power of Bismuth Telluride," *Proc. Phys. Soc.*, p. 638, vol. 71, 1958.
[17] H. J. Goldsmid, D. A. Wright and A. R. Sheard, "The Performance of Bismuth Telluride Thermojunctions," *Brit. J. Appl. Phys.*, p. 365, vol. 9, 1958.
[18] E. M. Putley, "Thermoelectric and Galvanometric Effects in Lead Selenide and Telluride," *Proc. Phys. Soc.*, p. 35, vol. 68B, 1955.
[19] T. C. Harman, "Multiple Stage Thermoelectric Generation of Power," *J. Appl. Phys.*, p. 1471, vol. 29, 1958.
[20] J. C. Read and C. F. Gimson, "A High Power Mechanical Contact Rectifier," *Proc. I.E.E.*, pp. 645-660, vol. 102A, 1955.
[21] F. S. Stein and E. W. Torok, "High Current Trinistors," Amer. I.E.E. Conference Paper No. CP58-1397, Feb. 1959.

WARMED DELIVERY VAN

A new way of life for the age-old craft of baking is being opened up by the use of electrical methods for storing bread and keeping it fresh. Many of the problems presented to the industry by the Baking Industry (Hours of Work) Act can be overcome if the baker can bake his bread when it suits him to do so. On their stand (D.1 Ground Floor) at the Bakers' and Confectioners' Exhibition (Olympia, 3 to 8 October), the Electrical Development Association will display equipment to show the baker how electricity can overcome labour difficulties by improving working conditions.

One interesting application on show might well be the answer to the problem many large bakers are experiencing in connection with bread delivery and the restrictions on night baking. This is an electrically-warmed delivery van, to keep the bread in prime condition overnight.

CALIBRATION OF MICROPHONES AT LOW FREQUENCIES

By G. Berry, B.Sc., A.M.I.Mech.E.

The design principles of an accoustic duct which may be used to calibrate microphones in the frequency range 30 to 320 c/s is discussed. A procedure for comparing the sensitivities of two microphones is described, giving an indication of the accuracy that may be obtained.

The duct consists of a long closed channel of square cross-section, shown in plan in Fig. 1. A loudspeaker at one end radiates sound which is constrained to a plane progressive wave formation by the parallel walls. At the far end, an absorbent section reduces reflection so that standing wave conditions are not established.

The design dimensions of the duct are dictated by the frequency range over which measurements are to be made. The length is governed by the lowest frequency, since the half wavelength of sound at this frequency must be not greater than the length of the absorbent section. The half wavelength of sound at 30 c/s is 18·5 ft approximately, and the length of absorbing section used is 20 ft. An additional free length of the order of a half wavelength is required between the speaker and absorbent. This free section allows the transformation from the conditions at the speaker diaphragm to the plane wave conditions required in the test section, and also ensures freedom from diffraction effects arising from the beginning of the absorbing section. The free length was chosen to be 15 ft giving a total length of 35 ft.

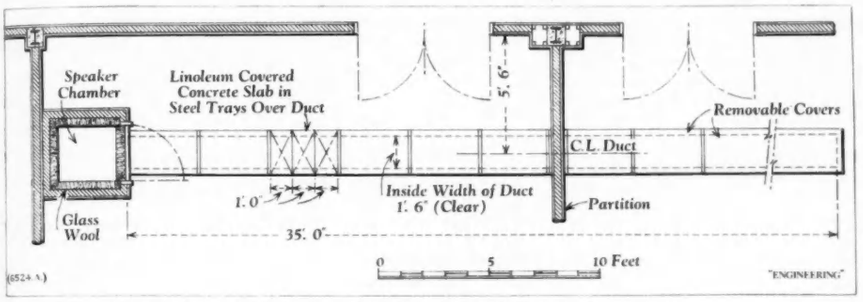


Fig. 1 Key plan of duct. The loudspeaker enclosure and test section are in one laboratory with the duct extending into an adjacent laboratory.

The upper frequency limit governs the duct section. With increasing frequency the wavelength of sound decreases and, when the half wavelength falls and becomes equal to the lateral dimensions, cross resonances occur. These influence the distribution of sound pressure along the longitudinal axis. The cross-section selected was that of an 18 in square, corresponding to the half wavelength of sound at 370 c/s approximately.

The loudspeaker selected should be as large as may be conveniently accommodated within the duct section to ease the transformation to plane wave conditions. It should have a fundamental resonant frequency below that of the lowest frequency of measurement so that the sound pressure level is not critically dependent upon frequency at any point. The speaker selected (Wharfedale—Type W15/CS) has a nominal diameter of 15 in and a cone resonance below 25 c/s. The rear of the speaker is enclosed to avoid nuisance, and the volume of the enclosure must be sufficiently large, see Fig. 2, that the speaker resonance is not materially raised by the consequent loading. It has been considered desirable that the enclosure volume should be of the order of 50 cu. ft.

Calibration of the Duct

For the comparison of microphone sensitivities, the duct is required to provide a volume of considerable magnitude in which the sound pressure level remains constant within close limits. It is not considered desirable that the two microphones to be compared should be placed side by side in the sound field, since their physical proximity might cause distortions in the field and consequent errors in the comparison.

A light monorail was installed extending over the whole of the free section. A light carriage, carried by runners on this rail, supported a moving coil microphone. Its diaphragm was at the centre of the cross-section of the duct and parallel to the direction of sound propagation.

The variation in sound pressure level along the longitudinal axis was measured at frequency intervals of $\frac{1}{3}$ octave from 20 c/s to 640 c/s.

The exploration of the vertical axis was confined to observations at a distance of 9 ft from the loudspeaker. In this instance, the microphone was raised and lowered by a cord passing through the centre of the $1\frac{1}{2}$ in hole in the inner concrete cover and through a small gap in the outer covers. The microphone was of the ball and biscuit type, and in order to cover the greatest possible length of this vertical axis, measurements were made first with the microphone diaphragm downwards and then upwards. A marked discontinuity was observed between the two sets of readings arising as the result of distortion of the sound field as the microphone approached and partly entered the hole. This suggested that the presence of this hole near the test section was undesirable.

Comparison of Microphone Sensitivities

Results indicate that the sound pressure level, in the section between 8 and 10 ft from the loudspeaker, and over the central section of 1 ft square, remains constant within close limits. The extent of the variation is not more than $\pm$ 0·1 dB from 50 c/s to 320 c/s and not more than $\pm$ 0·25 dB at 25 c/s. This indicates that microphones may be inserted in turn into the sound field without excessive care in locating and may be assumed to experience the same conditions.

In comparing the sensitivities of two microphones, the frequency of the source is first set and monitored by means of an electronic counter. The response of the measuring system to a known voltage in the microphone circuit is determined for each microphone in turn. The voltage is generated by passing through a measured resistance a current which is itself measured with the aid of a vacuo junction. These responses may be denoted as C_1 and C_2 respectively, on a decibel scale. The current to the loudspeaker is adjusted to a predetermined value as measured by a vacuo junction, and the response of the microphones to the sound field is measured in turn as R_1 and R_2 respectively, again on a decibel scale.

If the sensitivities of the microphones are M_1 and M_2 dB $\pm$ 1 volt per dyne per sq. cm, then:—

$$M_1 - M_2 = (C_1 - C_2) - (R_1 - R_2) \text{ dB.}$$

If the microphones are inserted on a substitution basis and a complete series of measurements at all frequencies made for each, then the frequency accuracy and current setting accuracy will influence the result. If, on the other hand, the microphones may be brought into the sound field alternately and rapidly, then the frequency setting error and loudspeaker current setting error disappear.

In order to achieve this alternation procedure, two parallel monorail systems have been installed at 2 in on either side of the longitudinal axis. A microphone carriage on one rail is linked to that on the other by an endless-cord system emerging from the duct at the end adjacent to the loudspeaker. Adjustable stops ensure that each microphone is brought, in turn, into the test section at the same distance from the loudspeaker. The microphone, which is not in this section, is some 8 ft away towards the absorbent section, and does not influence the sound field in the measurement area. The microphones may be alternated in a matter of seconds and any number of observations quickly made. In practice, the values of R_1 and R_2 are repeated to within the accuracy of scale reading, and it is only necessary to make a single confirmatory observation at each frequency to avoid gross errors.

Conclusions

(1) The volume of most-constant sound-pressure-level lies between 8 and 10 ft from the loudspeaker, with a section 1 ft square. (2) In this volume, the sound pressure level remains constant within $\pm$ 0·1 dB from 50 c/s to 320 c/s and within $\pm$ 0·25 dB at frequencies down to 25 c/s. (3) Where the sensitivities of two microphones are compared by alternately bringing the microphones into this test section, the accuracy of comparison is better than $\pm$ 0·2 dB at frequencies from 30 c/s to 320 c/s. (4) This method provides a quicker and more accurate method than the substitution method where only one microphone is placed in the duct at any one time.

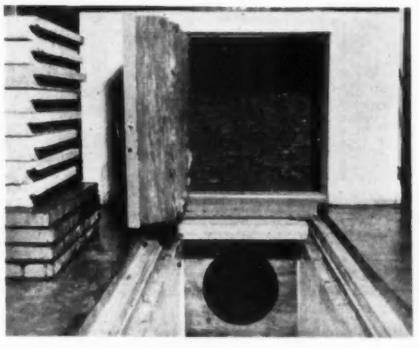


Fig. 2 The loudspeaker is on a baffle which separates the duct from the loudspeaker enclosure.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the advice on the design of the duct provided by members of the Physics Division of the National Physical Laboratory.

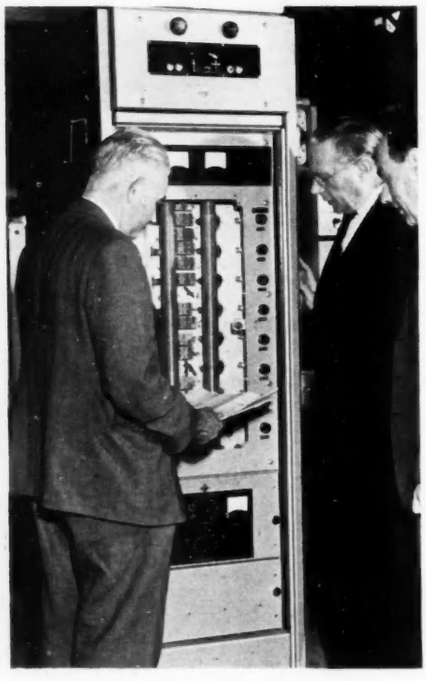
The work described above was carried out in the Mechanisms, Metrology and Noise Control Division of the Mechanical Engineering Research Laboratory (now National Engineering Laboratory) as part of the research programme of the Mechanical Engineering Research Board.

RADICAL DEVELOPMENT IN RADIO TRANSMISSION

New Wide Band System Dispenses with Operational Tuning

A radically new system of radio transmission, which will provide wide band amplification over the whole HF range, has been developed by Marconi's Wireless Telegraph Company Limited, Chelmsford, Essex. In addition to its bandwidth characteristics, the new system has several advantages in operation and maintenance.

The first transmitter to employ this technique is the Marconi HS113 which will operate at any frequency, or even simultaneously at several frequencies, in the range 2 to 24 Mc/s. Due to the novel design of its 1 kW HF amplifier, no retuning is required when changing frequency and both electrical and mechanical maintenance are simplified.



(Left) The new Marconi 1 kW transmitter, type HS113, is able to radiate two or more transmissions simultaneously. No tuning controls are required in the HF stages due to the use of a distributed amplifying technique.

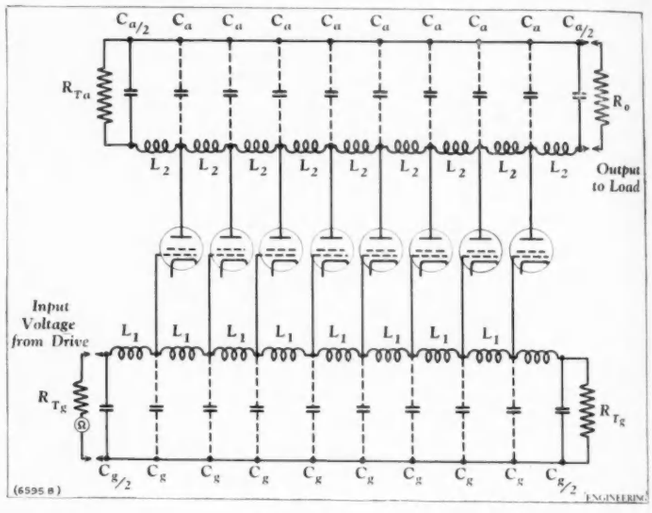
The design principle which gives rise to the improved bandwidth and operational simplicity is the use, for the first time in a power transmitter, of a distributed amplifier. This type of amplifier takes the form of two artificial transmission lines in which the shunt capacitances are formed by the interelectrode capacitances of the valves (see Fig. 1). The inductance separating individual valves effectively isolates their capacitances while the anode currents of the valves combine additively. Each valve is driven in succession, the time delay depending on the constants of the input line. The output line has identical delay characteristics and is fed by the anodes; half the anode current of each valve travels to the right and adds up in the output load, the other half goes to the left and is dissipated in the terminating resistor.

A compromise between a tapered and a uniform transmission line, making use of the advantages of each, has been achieved in the design of the anode circuit. The first stages of the amplifier take the form of a uniform line and, when the correct operating conditions have been achieved, the characteristic is changed so as to maintain a constant voltage swing on each succeeding valve.

This kind of amplifier possesses not only reasonable efficiency and good bandwidth but it is also insensitive to the nature of the load characteristics even when reactance is present to a degree corresponding to quite high standing-wave ratios. For instance, a 2 : 1 standing-wave ratio on the output feeder is quite permissible, producing only a slight reduction in output power.

In addition to the principal advantages of this new transmitter—increased bandwidth, easier tuning and the ability to radiate at several different frequencies—there are some useful subsidiary features. Foremost of these is that valve failure does not put the transmitter off the air. This is because the HF amplifier uses a multi-valve technique, so that if a valve fails the output power is merely reduced slightly. Also important is the fact that, due to the elimination of moving parts for retuning, mechanical failure cannot occur.

Since the modulation is applied at a low level in this equipment, it is possible to install the drive unit at a considerable distance from the amplifier, with distribution by coaxial cable. This is particularly advantageous for comprehensive station working, as the drives can be installed at a control centre and the amplifiers at any convenient point. Simple point-to-point radio links can also be operated to great advantage, especially where scheduled services are worked by one transmitter.


$C_{a/2}$ C_a C_a C_a C_a C_a C_a C_a C_a $C_{a/2}$
R_{Ta}
R_o
L_2 L_2 L_2 L_2 L_2 L_2 L_2 L_2 L_2
Output to Load
Input Voltage from Drive
L_1 L_1 L_1 L_1 L_1 L_1 L_1 L_1
R_{Tg}
R_{Tg}
$C_{g/2}$ C_g C_g C_g C_g C_g C_g C_g C_g $C_{g/2}$
(6595 B)
ENGINEERING

(Right) In its simplest form the distributed amplifier consists of two artificial transmission lines linked by a number of valves. The interelectrode capacitances of the valves form the shunt capacitances of the lines.

LABORATORY PLANT CONTRACT

It has been announced that Hawker Siddeley Nuclear Power Company Limited, have received contracts for the design of a glove box and vacuum melting furnaces from the United Kingdom Atomic Energy Authority.

X-RAY CAMERA IN A GLOVE BOX

A Unicam S.150 high temperature camera and 9 and 19 cm powder cameras have been installed in a standard Mark II Harwell glove box. The laboratory using the equipment contains two glove boxes, X-ray generator, and high-temperature control panel; it is equipped with normal services, and facilities for connecting the extract from the boxes to the extract plug of the building. In a Mark II glove box, the filled X-ray capillary tubes are attached to their supports prior to loading in a camera. The assembly is then transferred in a Perspex case to the camera glove box. (AERE C/R 2807, *Equipment for Obtaining X-Ray Diffraction Photographs of Alpha Active Materials*, R. W. M. D'Eye, I. F. Ferguson and R. S. Street, 4 pages, 8 figures, 3*s*.)

MEETINGS AND PAPERS

Institution of Heating and Ventilating Engineers

MANCHESTER
"Clean Air Act, 1956," by W. B. Kennedy. Manchester Branch. Engineers' Club, Albert Square, Manchester. Fri., 26 Sept., 6.30 p.m.

Institution of Mechanical Engineers

NOTTINGHAM
"Development of High-Temperature Materials," by R. E. Gresham. East Midlands Branch. The University, Nottingham. Wed., 23 Sept., 7.15 p.m.

Institution of Plant Engineers

BLACKBURN
"Films and Lectures," by E. A. Taylor. Blackburn Branch. Castle Hotel, Blackburn. Thurs., 17 Sept., 7.30 p.m.

CARDIFF
Technical films on lubrication and fuel oils, exhibited through Shell-Mex and BP Ltd. South Wales Branch. South Wales Institute of Engineers, Park Place, Cardiff. Tues, 22 Sept., 7.30 p.m.

ROCHESTER
"Industrial Law and the Engineer," by R. Cambridge. Kent Branch. King's Head Hotel, High Street, Rochester. Wed., 16 Sept., 7 p.m.

Institution of Production Engineers

SHEFFIELD
Discussion on "Production Joinery." Sheffield Graduate Section. Rothervale Manufacturing Co., Ltd., Woodhouse Mill, near Sheffield. Mon., 14 Sept., 6.45 p.m.

Operational Research Society

LONDON
"Towards the Unification of Military and Industrial Operations Research," by Georges Brigham; "Ethical Commitments of Operations Research," by Professor C. West Churchman; and "Operations Research and Psychoanalysis in the Solution of Management Problems," by Dr. Herbert Holt. These three speakers are American operational research workers who have been attending the conference of the Institute of Management Sciences in Paris. Royal Society of Arts, John Adam Street, Adelphi, WC2. Mon., 14 Sept., 2 p.m.

Physical Society

LONDON
Charles Chree Prize Lecture on "Weather Forecasting as a Problem in Fluid Dynamics," by Dr. R. C. Sutcliffe. Imperial College, South Kensington, SW7. Thurs., 17 Sept., 6 p.m.

University of Durham King's College

NEWCASTLE UPON TYNE
Symposium on "The Treatment of Waste Waters," at the Public Health Engineering Section, Department of Civil Engineering, King's College, Claremont Road, Newcasle upon Tyne. Mon., 14 Sept., 9.30 a.m. and 2.15 p.m.; Tues, 15 Sept., 9 a.m. and 2.30 p.m.; Wed., 16 Sept., 9.30 a.m. and 2.15 p.m.; Fri., 18 Sept., 9.15 a.m. and 2 p.m.; and Sat., 19 Sept., 9 a.m. Various visits and excursions, Thurs., 17 Sept.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this feature should reach the Editor not later than three weeks before the date of the meeting.

Institution of Heating and Ventilating Engineers, 49 Cadogan Square, London, SW1. (SLOane 3158).
Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, London, SW1. (WHItehall 7476.)
Intitution of Plant Engineers, 2 Grosvenor Gardens, London, SW1. (SLOane 0469.)
Institution of Production Engineers, 10 Chesterfield Street, London, W1. (GROsvenor 5254.)
Operational Research Society, 64 Cannon Street, London, EC4. (CITy 1800.)
Physical Society, 1 Lowther Gardens, South Kensington, London, SW7. (KENsington 0048.)
University of Durham King's College, Claremont Road, Newcastle upon Tyne 1. (Newcastle 29963.)

On the Shelf

By Frank H. Smith

Anybody with half an eye (and most of us can muster that) must have noticed the increase in use of Venetian blinds, both for the "contemporary" coffee bar and for the private house. The use of aluminium in various colours or plastics has made this fashion possible and acceptable because of ease of cleaning, lightness of weight, and so on. All this has been said before in hundreds of women's columns but my object in talking of them is to call attention to something that the average half-eye will not have seen. Not once but twice I have seen them referred to as venetion (*sic*) blinds, and when the second occasion was the ADA's *Aluminium Courier* I thought it high time to refer to the dikker. It's Venetian all right. I am told, by the way, that translating machines have difficulty in distinguishing between Venetian blinds and blind Venetians. The same number of the *Courier* reviews "Proceedings of a Symposium on Aluminium in Packaging" (which is 15*s* from the ADA) and I see that the *final* paper in the symposium was "Aluminium Closures." Could anything be more apt?

It is quite likely that readers of this journal will not, ordinarily, see aeronautical journals and particularly German aeronautical journals. They may, therefore, miss some interesting references in *Luftfahrttechnik* for 15 July: seven pages on "Steels for Hypersonic Missiles" with 29 references, six pages on "Highly Heat-resistant Steels and Alloys for the Construction of Aircraft Engines" with 23 references, six pages on "The Processing of Titanium and Titanium Alloys" with 31 references, and a short note on beryllium as a structural material in aircraft production. The other article deals with self-locking nuts using a plastic. Should all this give an impression of bi-lingualism in your columnist let me add that *Luftfahrttechnik* supplies a tear-out index in French, English and the home-tongue. Mention of all these "ium" materials reminds me that I must ask an American some time why they have aluminum but not beryllum, niobum and cadmum.

Last November (p. 613) I remarked on a new bibliography by a Mrs. Beryl Board on *The Effect of Technological Progress on Education*. I then said that most of the stuff had actually been read by the compiler. This, I regarded as unique. Mrs. Board has now sent me a copy of the completed bibliography (classified 1945-57) and tells me that the asterisks which denoted an unread item in the draft have now been eliminated as inapplicable. In other words, she has actually read every item in her compilation. This achievement ranks an entry in the *Guinness Book of Records*. Mrs. Board is no longer with the Institution of Production Engineers, but inquiries about the bibliography should be addressed there. Their address is 10 Chesterfield Street, London, W1, and the price is 14*s* 6*d*. Allow a shilling for postage.

A rather plush journal called *Camera* comes from C. J. Bucher AG., Lucerne. It is 6*s* 6*d* a copy or 50*s* a year and the particular one they sent me is devoted to aerial photography. It deals with all aspects: scenic, archaeological, surveying, and so on. More picture than text but beautifully produced.

From the National Research Council, Division of Building Research, Ottawa, can be obtained delicate blue cards listing supplements to their original list of publications issued in March, 1958. The July supplement is No. 9 so if you have none of the previous ones you had better ask for them.

A UNESCO publication from the Ministry of Education looks interesting. Called *Technical and Vocational Education in the USSR*, it is a bibliographical survey by M. I. Movšovič and costs 5*s* from HMSO. Each title has a lengthy abstract and they are grouped in elementary, secondary and higher parts.

GERMAN THERMODYNAMICS COMES DOWN TO EARTH

Grundlagen der Chemischen Technik. Vol. IV: Wärmeaustauscher (Fundamentals of Chemical Technique. Vol. IV: Heat Exchangers). By ROMANO GREGORIG. *Verlag H. R. Sauerländer and Company, Aarau, Switzerland.* (45 *DM*)

Gleichgewichtsgase der Verbrennung und Vergasung (Equilibrium Gases of Combustion and Gasification). By A. GRUMBT. *Springer-Verlag, Heidelberger Platz, 3, Berlin-Wilmersdorf, Germany.* (26·40 *DM*)

Kesselspeisewasser (Boiler Feed Water). By ROLF FREIER. *Walter de Gruyter and Company, Genthiner Strasse 13, Berlin, W35, Germany.* (38 *DM*)

Richtlinien für die Aufbereitung von Kesselspeisewasser und Kühlwasser (Instructions for the Treatment of Boiler Feed Water and Cooling Water—prepared by VGB, Vereinigung der Grosskesselbesitzer, the German Association of Large Boiler Users). *Vulkan-Verlag, Hollestrasse 1, Essen, Germany.* (46 *DM*)

The dichotomy of mind and body in medicine has thrown up a completely new branch of healing—psychosomatics, although the cult has not yet crossed the Atlantic in any strength. In engineering, however, the opposite pulls of practice and theory, of bench experience and lecture theatre knowledge have not yet been convincingly unified on either side of the ocean. It is, therefore, very interesting to find an attempt being made in Germany to resolve at least some of the difficulties. Verlag H. R. Sauerländer and Company have planned a series of some 40 volumes under the general heading of "Fundamentals of Chemical Technique," of which the first six have been published, the work under review being the fourth. It is proposed that a philosophy of theoretically-based practicability shall underlie them all.

It is appropriate to talk of philosophy when reviewing any German book which strays however briefly from the hard road of practice, for generalisations float very easily above the plane of reality in the German language. This is, perhaps, a contributory feature which normally makes German textbooks difficult reading; it is a pleasure, therefore, to find such an admirable book as Professor Gregorig has produced. He has indeed succeeded in combining the theoretical thermodynamics of heat transfer with practical details of heat-exchanger construction and operation. He has dealt concisely with details where others have preferred unnecessary elaboration—particularly in the difficult field of dropwise condensation—and he has spread his net extremely wide in his references: the American and United Kingdom sources exceeding the German in most cases and the total number by far exceeding the average found in otherwise comparable textbooks.

However, in recommending a book in a language foreign to English-speaking engineers, it is most probably more important to review the use to which they can put the book than to outline the contents or detail the coverage of particular subjects. Besides the references, certain other points in *Wärmeaustauscher* stand out with equally refreshing clarity. For example, there is an extremely useful index of symbols which lists the letters, English and Greek, and the purely mathematical symbols used throughout the book, giving not only the simple definition as is common in English textbooks but also the page where the basic equation—the real definition—is first used. This is particularly necessary as there is no complete international agreement yet on symbolisation: "zeta" here being used, for instance, for the friction factor "*f*." The diagrammatic inclusion of what might normally be thought of as "workshop practice" drawings is also admirable. The omission of a number of graphs which one might have expected to find is, however, rather disappointing and somewhat reduces the immediate practical use of the book to the engineer, to whom such graphs are bright illuminations amidst the murk of verbiage. But for those who intend to turn to the text of what can be judged on the whole a very rewarding book there is much that is satisfyingly new.

The reader is taken further than is usual in such matters as the calculation of the parameters of condensing preheaters; in Nusselt's theory of surface condensation at variable wall temperatures; and in the influence of pressure loss of steam flow through a tube bundle—not omitting the effect of surface roughness. The only obvious lack, in a book for a practical engineer already familiar with basic principles and anxious to learn more, is consideration of the design and construction of liquid-metal heat exchangers, which should have been included in a survey so modern as this.

Dr. Grumbt's book is also a survey but his much slimmer volume attempts nothing more adventurous than the collection, annotation and correlation of the calculations scattered throughout the literature dealing with the dissociation of gases at high temperatures and pressures, the concentration and the equilibrium of the gaseous constituents, and thermodynamically related problems. The literature searched excludes almost all non-German sources, which is not surprising when it is realised that the aim is to simplify the understanding of combustion and gasification techniques for the German engineer. For in this book the theme is that dissociation has always been something which is not clearly understood and that some knowledge of this subject is valuable—although perhaps more to the theoretical than to the practical engineer. For the latter, entropy and enthalpy are well covered, but with no new thinking incorporated; there is merely a presentation of known facts and tables which may be found in standard English textbooks. The graphs are nevertheless quite useful, though in the main this is scarcely a book to be recommended to anyone whose command of technical German is at all limited.

Indeed the question of the extent to which a command of a foreign language is required in engineering—whether theoretical or practical—is highlighted by all the books under review. There is such a flood of American and English literature, through which an engineer must-wade if he is to keep abreast of modern developments, that he can never be sure whether he has read enough in his own language let alone chide himself for not having mastered the intricacies of another. Besides, if he is to open up the enormous field of engineering experience that is there for those with command of a foreign tongue, ought it not perhaps to be Russian he should study?

Maybe a hint to one solution is contained in Dr. Freier's book on the technology and analysis of boiler feed water, in his handling of references. As this is somewhat more of a works handbook than a textbook his references are limited in number but his sources do include some American publications and it is the principle of their handling which is instructive. An abstract is given of the work quoted in reference, this abstract being of sufficient length to indicate the relevance of the work; tables and formulae, where appropriate, being included.

It is not clear from the text what permissions were negotiated or whether it is felt that these abstracts, although of considerable length, do not contravene any copyright. They certainly broaden the scope of the book and lead to the suggestion that this method of dealing with references could well be adopted by English-speaking authors who have consulted foreign works, either in the original or in translation. The author wishing to quote a particular reference is in the position of knowing just what part

of the original source is most highly relevant to his work and can accordingly make the most appropriate abstract. The reader can achieve some idea from this of the scope of the work referred to—a work which he might not understand and to which he might not be in a position to make reference even if he could. Apart from the lesson to be learnt from this feature, however, there is little of interest to the non-German speaking reader. The book itself is divided in such a way that each section is independent of the others and each starts with a fundamental broad outline of theory, proceeding swiftly to practical details. It is the publisher's intention to produce, by this means, a synthesis between a textbook and a works-manual. However, for a foreign-language textbook to merit the effort involved in translation it must offer something more than is available in one's native tongue. In this case it must offer more than a basic chemistry of water and a recognition that feedwater treatment is needed to prevent corrosion or scale formation and deposition.

It must contribute to the discussion as to whether or not deoxygenation of feedwater is really necessary. It cannot just be accepted without at least offering some figure between 300 and 350 lb per sq. in operating pressure for power boilers, above which it is necessary and below which special provision need not be made. It must also contribute to the examination of pH as a measure of feed water quality and the possibility that pOH might be more suitable in view of its greater freedom from temperature dependence. But Dr. Freier's book does not set out to do these things. Nor does the VGB handbook, which in fact sets out to be an instruction manual for engineers who prefer, rather than to go to a textbook, to find their solutions by searching among the many practical examples thrown up by everyday experience.

In this it succeeds very well. A complete revision of the 1950 VGB handbook, it is considerably enlarged and covers the setting-up of water treatment installations, their care, maintenance and supervision; it devotes space to examination of complete and partial demineralisation, to removal of calcium carbonates and to evaporation.

The notes on supervision relate particularly to its practical aspects as do the notes on the upkeep of the steam unit, condenser maintenance and the treatment of cooling water. But this is no condemnation of a book which calls itself the "Standard Work on Water Treatment," it merely indicates that, in spite of a really excellent index, it will be difficult for anyone who is not fully familiar with the vagaries of technical German to learn much from it. The position is, in fact, very well exemplified by this book which, admirable in every way, nevertheless cannot be put to one of the most significant uses of foreign literature—finding out what the other fellow is doing. But perhaps the pull between practice and theory, between bench experience and boardroom knowledge is here best resolved by the simple injunction: "Go there and see for yourself."

S. MAKEPEACE-LOTT.

The Reviewers

Mr. S. Makepeace-Lott has until recently been abstractor in the research department library of Babcock and Wilcox Limited, and is now in the London office of the United Kingdom Atomic Energy Authority. For three years he read engineering at Liverpool University and subsequently spent two years at Vienna University, where he studied semantics and empirical logic. He is a member of the Society of Authors and has had several light novels published.

Mr. Rodney W. Collins is works chemist responsible for service to the impact extrusion factory and for the gravure printing section of Venesta Limited. He has served with the company for 12 years, much of the time as collapsible-tube works chemist in the packaging division. He became an associate of the Royal Institute of Chemistry in 1955, and is a member of the Oil and Colour Chemists Association. He is also a member of the chemists' committee of the Collapsible Tube Manufacturers' Association.

SPECIAL DISPENSATION

Pressurised Packaging (Aerosols). By A. HERZKA and J. PICKTHALL. *Butterworths Scientific Publications, 4 and 5 Bell Yard, London, WC2* (63*s*); and *Academic Press Incorporated, New York, USA.*

It is remarkable that the Aerosol industry has grown up in this country to its present important position without a parallel appearance of technical publications on the subject, apart from articles in technical journals. The arrival of *Pressurized Packaging* (*Aerosols*) means that there is now available a single volume which fills this gap in books on modern packaging.

This 411-page book is well bound and clearly printed on good quality paper and is divided into three main sections plus several appendices. The authors commence with a concise history of aerosols, where it is surprising to learn that the development of aerosol-type packs can be traced back as far as the early thirties, and that there is actually an American patent dated 1889. General acceptance of the aerosol however, followed its successful use as an insecticide dispenser during the Second World War and the United States Department of Agriculture, who developed this application, can claim to be the instigator of pressurised packaging in its modern form. It may not be generally known that from ½ million units in 1950, consumption in this country alone has risen to 12 million by 1957.

The second section of the book is devoted to components and techniques, and the chapters in this section, concerning propellents, dispenser components, filling techniques and laboratory evaluation, are very comprehensive. Particularly valuable is the description of laboratory work on experimental formulae, which includes photographs of apparatus that the authors have developed during their study of aerosols. From articles in trade journals it is known that Mr. Pickthall feels strongly about the dangers of unprotected glass aerosol containers, and convincing photographs of what can happen when such a container is dropped are included.

The third and largest section gives formulations of most preparations at present filled from perfumes to paints and varnishes, and from foods to fire extinguishers.

Supplementing the three sections, there are five appendices on technical terms, trade names, British formulation patents, industrial methylated spirit, and a world directory of suppliers. As well as a comprehensive subject index to end the book, there is a useful list of references at the end of each chapter which may be consulted for further reading.

The authors are two of Britain's leading authorities on aerosols, and as is to be expected they deal comprehensively and clearly with their subject. It seem obvious that in their view a scientific approach is necessary. It is true to say that for a full understanding of aerosols, a certain knowledge of physical chemistry is desirable, and the excellent phase diagrams given in the chapter on propellents can be interpreted the more easily if the reader is familiar with the phase rule and vapour pressures. This is not to say that the volume is of limited use unless the reader is a physical chemist, for it deals with the subject in a logical readable manner.

Pressurized Packaging Aerosols then is an excellent reference book for those new to the field who are considering this particular packaging medium for their product, and also for those who have a general interest in the subject.

RODNEY W. COLLINS

NEW BOOKS

Modern Foundry Practice. Edited by E. D. HOWARD. Third Edition. *Odhams Press Limited, 96 Long Acre, London, WC2.* (30*s*)

A product of "eighteen specialist authors" who, in some cases, have been revised. The third edition embodies modern developments and remains a book for all stages from apprentice to executive.

Chemie des Ingenieurs. By E. BRANDENBERGER, *Springer-Verlag, Reichpietschufer 20, Berlin W35. Germany.* (*DM* 24)

The author is at the Technical High School at Zurich and his book is an introduction, for engineers, to materials and chemical reactions. Well indexed and with a bibliography to each chapter.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Machine Tools

Carbide Drills. LORANT ENGINEERS (LONDON) LTD., 65 High Street, South Norwood, London, SE25. Range of Westa-Widia tungsten carbide tipped twist drills. Catalogue.

High Speed Press. FRANK LEWIS & CO. (LONDON) LTD., 65 St. Pauls Churchyard, London, EC4. The Norton 7½ ton high speed hydraulic press has six approach speeds and 36 ram speeds. Rate variable up to 600 strokes per min. at ⅜ in stroke. Leaflet.

Tool Holder. JAMES NEILL & CO. LTD., Napier Street, Sheffield 11. Small cutting-off tool holder in the Eclipse range. Capacity $\frac{5}{16}$ in for use on small lathes. Leaflet.

Lathe Tools. JOHN BAKER & SONS LTD., Monmouth Works, Malinda Street, Sheffield 3. "Lighthouse" series of lathe tools tipped with cobalt high speed steel. List of sizes and shapes.

Radial Drill. QUALTERS AND SMITH BROS. LTD., Barnsley, Yorks. Column radial drilling machines 1½ in capacity in steel. Model E3 has 46 in swing, model E4 58 in swing. Leaflet.

Saws. FIRTH BROWN TOOLS LTD., Speedicut Works, Carlisle Street East, Sheffield 4. Speedicut Mitia carbide-tipped saws; cutting speeds 8,000 to 12,000 ft per min. for plastics, timber and non-ferrous metals. Sizes from 4 in to 48 in dia. Folder.

Tube Drawing. HEAD WRIGHTSON MACHINE CO. LTD., Commercial Street, Middlesbrough. Tube draw benches for automatic and semi-automatic operation. Leaflet.

Transport

Disc Brakes. DUNLOP RUBBER CO. LTD., Foleshill, Coventry. "Safety Plus" is a booklet that describes the history of braking, and of the disc brake in particular.

Service Charts. LEYLAND MOTORS LTD., Leyland, Lancs. Wallchart 101 deals with fuel injectors for all Leyland engines; chart 102 is concerned with under- and oversize components and with shims and packing washers.

Traffic Lights. AUTOMATIC TELEPHONE AND ELECTRIC CO. LTD., Strowger House, Arundel Street, London, WC2. The type 54 Electro-matic controller for traffic light installations is described in booklet No. 1365. Electromatic vehicle detector type FS is detailed in No. 1415.

Diesel Locomotive. BRUSH ENGINEERING CO. LTD., Loughborough. The 1,250 h.p. A1A-A1A locomotive as supplied to British Railways (Type 2) is described in detail in publication No. 71108.

ABOARD THE SKIPJACK

A Special Correspondent Examines the Design of a Nuclear Submarine with Tear Drop Hull

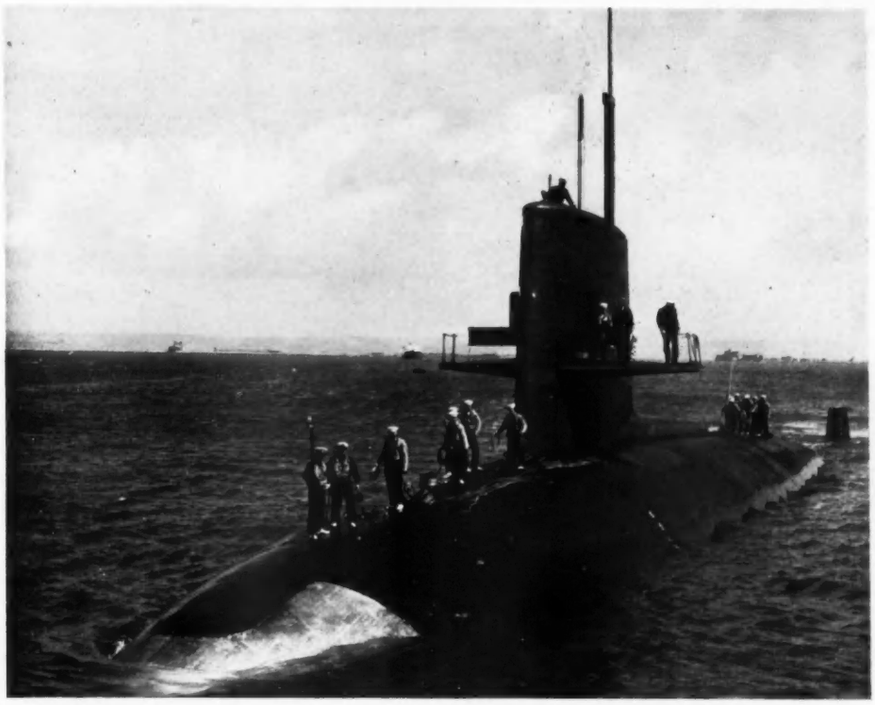
Skipjack, the United States Navy's latest atomic submarine, visited Portland harbour here last month. The vessel differs radically from her predecessors, for she has a blunt-nosed, football-shaped hull (in itself an important development and the first for a combatant ship) and no superstructure. She is thus hydrodynamically better than any other submarine and her submerged speed is the highest ever.

Low Drag Form

To the visitor, the most obvious novelty is the " tear drop " shape of hull form combined with a tall conning tower, now called " sail " by the United States Navy. An almost complete elimination of " appendages ", and horizontal sail planes located fairly high up on the " sail " are other distinctive features.

The low drag concept was developed and tested initially in USS Albacore, which had conventional machinery with very powerful batteries, just sufficient to prove the speed and other desirable qualities over a short period.

In considering the relative resistance qualities, there is probably no very short answer to the exact difference between Skipjack and her more conventional predecessors with their greater length-to-beam ratio, as well as appendages, openings, saddle tanks, superstructures, and so on. Undoubtedly there is a fairly marked reduction in drag because the " tear drop " shape leads to reduced wetted surface for a given volume, as compared with a longer and thinner hull. For minimum area the sphere would be the winner on that score alone. However, much resistance and " noise " are involved where departures from the true body of revolution occur, as for superstructures, etc. Probably the Skipjack can claim an overall advantage of at least 30 per cent in resistance for a given speed.



Reactor and Engine Room

The pressurised water reactor (PWR) type of machinery results from experience in the Nautilus and though basically the same, occupies much less space and weighs less.

A diagrammatic lay-out of the machinery (page 167) shows that two main turbines (A) drive into common single shaft (B) which, in turn, drives a five bladed propeller (C). Incidentally, this could be seen near the surface in the relatively clear waters of Portland harbour.

In emergency (as a " get you home " precaution) an electric motor mounted integrally with the propeller shaft can be driven from the battery, from small diesel engines or from a.c./d.c. generator sets.

The lay-out of the gearing coupling the main propelling turbines to the single shaft would be interesting, and it must be assumed that double reduction is employed.

The reactor compartment equipment includes one reactor (D) and two primary loops. The reactor gives up heat to the primary coolant water, which is then forced through the steam generator tubes (E) where it gives up heat to form steam on the shell or secondary side of the boiler. The primary coolant is then pumped back into the reactor where it is heated again. The primary coolant water is kept pressurised to ensure that boiling will not take place in the reactor. The secondary system produces steam. It is completely isolated from the primary system since the primary water goes through the tubes of the steam generator while the secondary water (which boils to make steam) is on the shell side. Steam rises to the top of the steam generator where the water carry-over is separated from the steam. The dry saturated steam then flows back to the engine room where it drives the ship's service turbo generator sets (F) and the main propulsion turbines.

Between the vital reactor and propeller, almost every electrical and mechanical system is installed in duplicate on the port and starboard sides of the ship. In addition, every control feature of the power plant and the ship has at least one backup method of operation, in addition to normal operation. The single propeller is made to the same strength standards as for an icebreaker, while the reactor is designed to be fully shock resisting.

When the reactor is in operation, the lower level of the reactor compartment is kept isolated and personnel cannot enter this space. Within a few minutes after shutdown the lower level reactor compartment can be entered to perform maintenance work.

The shield of the reactor reduces the radiation to such a level that, during a cruise lasting the life of the reactor, the average crew member receives less radiation than he would during a lifetime from X-rays and cosmic rays and natural radioactivity in the sea, air, drinking water and ground. In one year of operation, the average crew member receives under the Bureau of Standards allowable radiation dose for one week.

Controllability

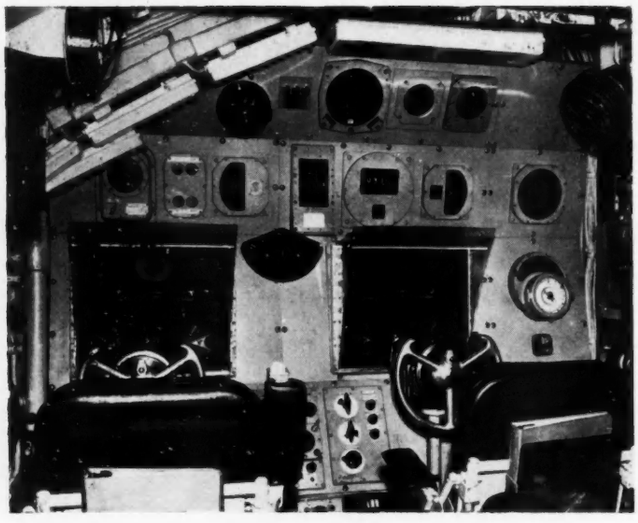
Much time and scientific effort was devoted to the control and manoeuvring of this type of high speed warship. At the David Taylor Model Basin a control booth is erected where the ship can be " flown " on dry land. A mock-up of the control system is arranged in a laboratory so that the performance of the ship may be simulated as a result of control column movements. The differential equations of motion are solved electronically to give the displacements appropriate to each axis of freedom.

During a visit last year the writer was given the opportunity to try his hand at this game. After only a few minutes he was informed that he had shown promise but was at that instant 100 ft above the surface ! This emphasises the reason for such careful study of the control problem. Because of the high submerged speeds, only a very few seconds is needed for something quite unpleasant to happen if the controls are incorrectly handled to only a small extent near the surface.

Flying Analogy

Much has been said about the analogy with flying and indeed her officers talk of " flying her " and compare the qualities in manoeuvre with

those of an aircraft. There is, of course, superficially a valid analogy, to the extent that both "vehicles" operate fully submerged in a fluid. To some extent the problems of control must be comparable because the control surfaces provide their forces and moments through dynamic effects resulting from the ambient fluid flow. There are, however, important differences, despite the fact that the control station has much the appearance of a flight deck in a modern aircraft, as is apparent from the illustration above. The analogy is far closer to an airship, where buoyancy effects play a large part.



(left) The diving control station of the Skipjack, showing aircraft-like controls and instrumentation.

Though the column operates the horizontal planes or elevators, the wheel (instead of producing a moment in the rolling plane by means of differentially operated ailerons) operates the rudder. It should be mentioned that the function of the sailplanes seen high upon the conning tower and the elevator planes aft is to control longitudinal trim. They cannot supply a rolling moment as they cannot move differentially port and starboard. The sail planes are a substitute for the more usual forward hydroplanes which are understood to suffer from a most unsatisfactory flow condition if fitted in way of the nose of the hull in this particular configuration, and at this particular speed and degree of manoeuvrability. The inward bank which is so necessary for a really high speed turn must, therefore, be provided by other means.

We were told that this quality (it is one of the most outstanding features of the craft) is a result of the general design and layout of the various surfaces and centres of effort and gravity.

It must be assumed that the inward "bank" arises because the centre of effort of the "sail," when presented at an angle of attack to the ambient flow, provides the necessary heeling moment, which will be roughly proportional to V^2. This moment will result in an angular velocity in heel until equilibrium is restored by a displacement of the c.g. (which is below the axis of roll) in the opposite direction. The natural damping in heel of such a form cannot be great, so it would seem to be quite a problem to produce a moment that does not unduly accentuate the inward heel at high speed but which builds up according to a square law while the restoring force of gravity is only linear with the angle of heel up to 90°!

The very enthusiastic ship's company told us that, when manoeuvres are about to commence, they have to brace themselves in such a position that they can not be thrown about. The forward-facing pilots' seats were fitted with lap straps but not shoulder harness.

The work of controlling the ship in manoeuvre can be divided between two control stations or carried out by one only. Most of the time, an auto-pilot can provide the necessary guidance from a gyro based guidance system.

Internal Economy

Habitability and the general aesthetics of the living spaces have been carefully studied, which is not surprising since the operational role of such a ship can easily envisage a matter of weeks submerged. The general effect is cheerful, while formica trimmed with stainless steel or aluminium is much used for panelling.

The usual television sets and Juke boxes were in evidence on the mess decks, and a cinema programme could be produced at short notice. Each bunk is provided with a ventilation supply somewhat similar to those on aircraft, though the air was "cooled" for tropical use and even for UK use in this case. A most ingenious reading light is supplied at the head of each bunk. It incorporates a vapour lamp about 18 in long, carefully reflected and shielded so that the sleeping neighbours are not disturbed.

We were told that when the concept of the nuclear submarine was first put into practical operation (and as a result of careful study by a medico-psychological team) it was appreciated that the welfare of the "boys" required certain hours of darkness to compensate for the shore-going night and day they were missing.

Performance and Other Characteristics

Compared with the Nautilus, Skipjack is (on the authority of Jane's "Fighting Ships") a lot smaller. Length is 252 ft against 320 ft for the Nautilus, with a larger beam at maximum width. Likewise, the displacement is about 2,500 tons against something more than 3,000 tons. Probably as a result of this, the interior layout of Skipjack gives a much less spacious effect, though still attractive, certainly in relation to conventional submarines.

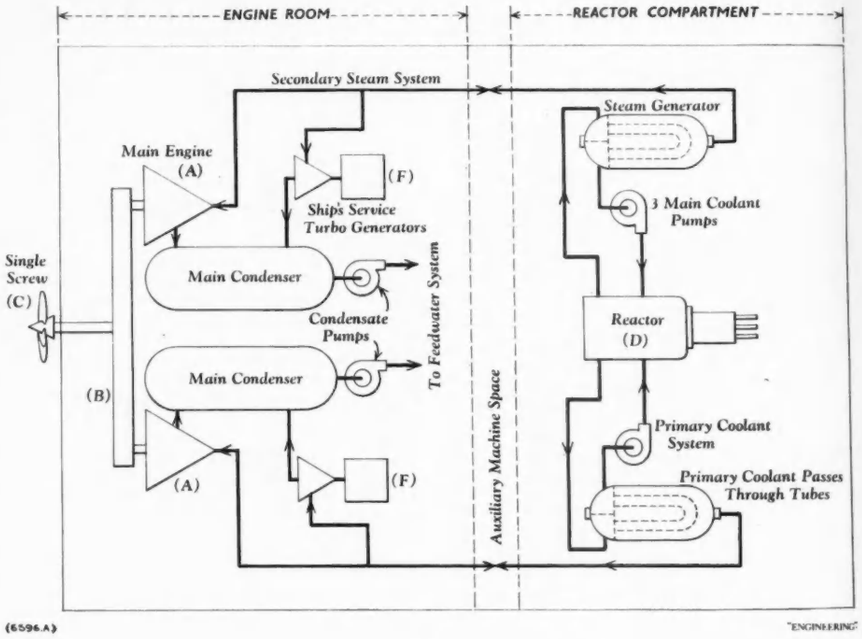
As a result of the reduced dimensions (including length) associated with much the same available power, we must expect the Skipjack to have more speed. It will be appreciated that below a depth approximately equal to the length of the ship, wave-making resistance (which is a function of length or square root of length, to be more accurate) is not a factor to be taken into account, so we need not expect the reduced length to have any ill effect on speed qualities.

Nucleonics Laboratory

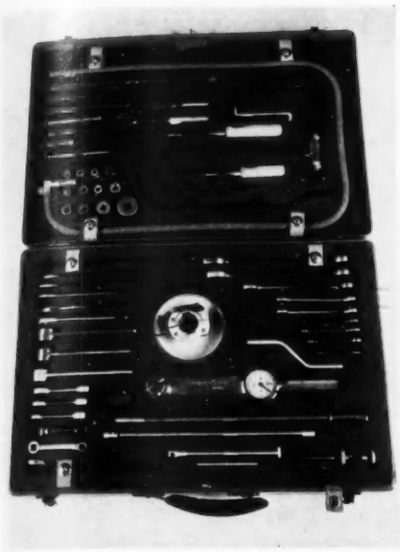
A nucleonics laboratory is provided where tests of radiation level are carried out on (for instance) samples of condensate. In addition, each man carries his own equivalent of the geiger counter, which has to be tested at least weekly. We, as visitors, were given, besides an excellent little brochure, an instrument like a pocket pen with a lens at one end, through which to read a radiation level marking by holding to the light. This had to be returned after the visit and the reading checked as the same as on arrival.

The reactor was "critical" at the time we went round, as the steam turbogenerators were providing the ship's load. Usually the diesel generator does this but it was under repair.

It was a delight to talk to these enthusiastic young men who were obviously conscious of the honour of serving in what is undoubtedly the forerunner of the warship of the future. They at least had no doubt as to who would win a contest of speed and manoeuvrability between Skipjack at 30 knots plus and a destroyer on the surface. They consider their speed in manoeuvre alone would shake off any possible surface attacker. Truly this must represent "the shape of ships to come."

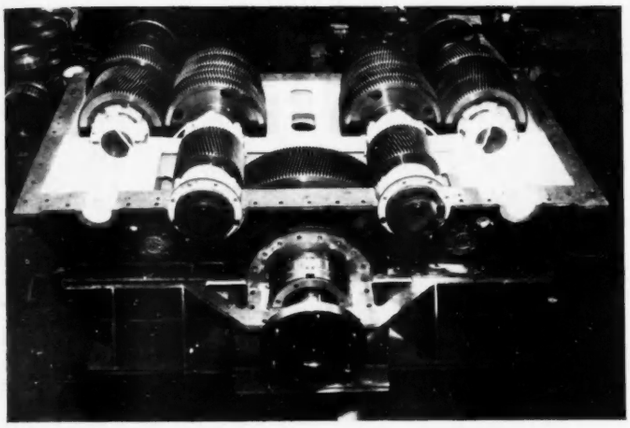


(below) Arrangement of the nuclear propulsion machinery in the USS Skipjack.

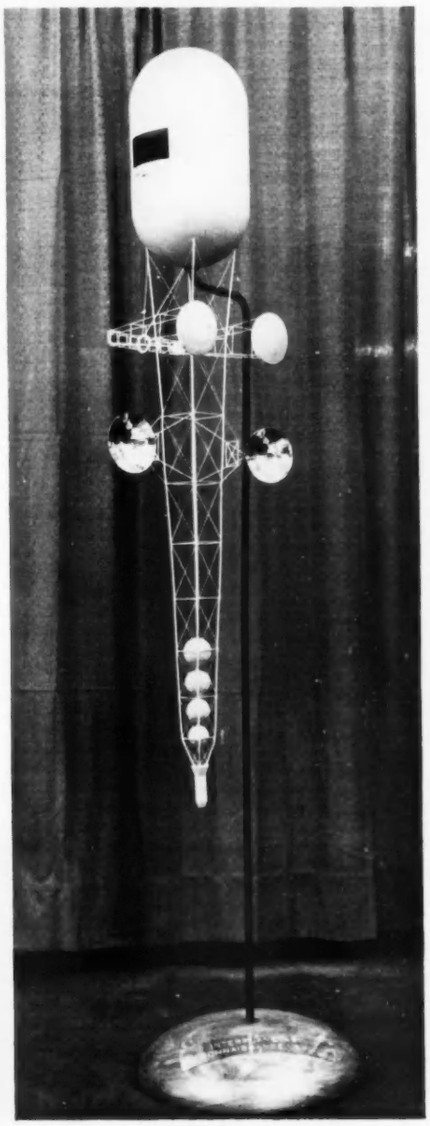


(*Above*) *Tool kit for Rolls Royce aero engine operators. The box is of glass fibre reinforced plastic.*

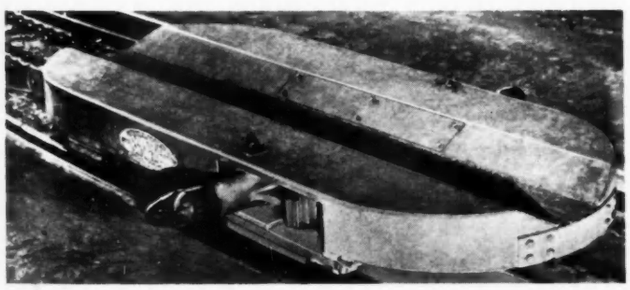
(*Above*) *This is how the Northrop Gyro-Glide monorail system would look on the Los Angeles, California, freeway. Aircraft type construction would be used for the cars. Operating speed: about 50 m.p.h.*



(*Right*) *Model of a US manned orbital or interplanetary reconnaissance vehicle design.*

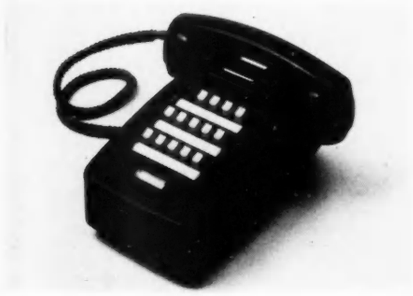


(*left*) *Twin-input, single-output, oil-operated, reverse-reduction gear with two speeds ahead, for the Aden Port Trust tug, Sir William Luce.*

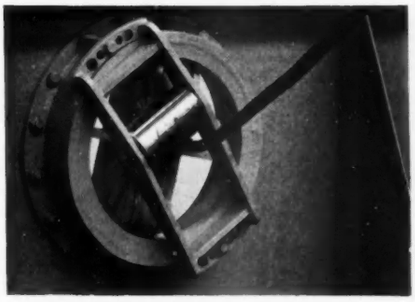


(*Left*) *Beetle power propulsion unit can push a railway wagon up a 1 in 4½ gradient.*

(*Below*) *Moulded plastic is used for the outer casing and handset of this intercom telephone.*



(*Below*) *Redesigned Port Colborne fairlead (left), with roller, compared with a standard fairlead.*



NOMOGRAM FOR FINDING CONVEYOR BELT WIDTH

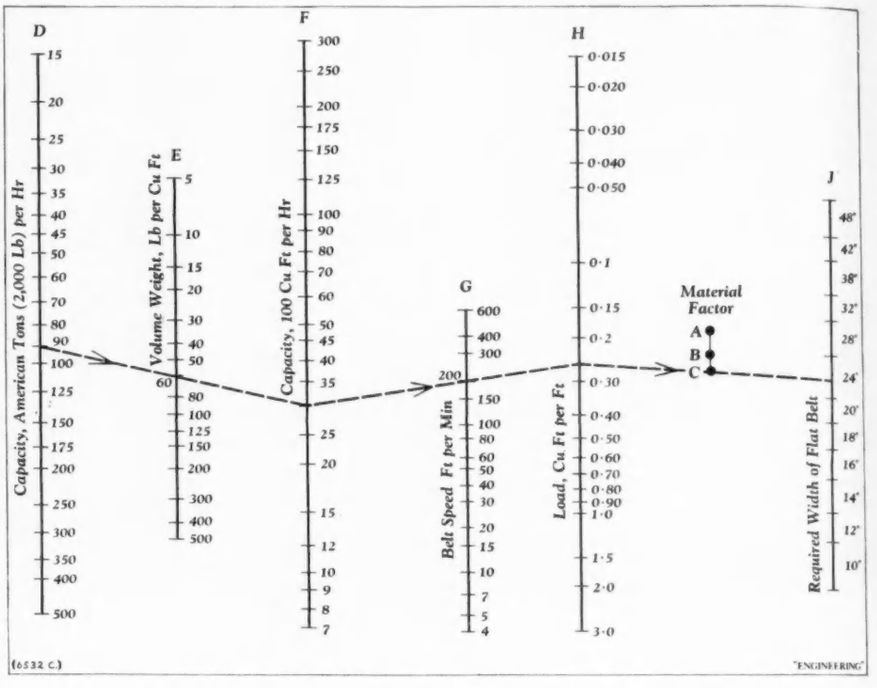
This nomogram (prepared by the Sandvik Steel Band Conveyor Company Limited, of Selly Oak, Birmingham) makes it easy to find the proper conveyor-belt width for handling bulk materials.

All you have to know is the tonnage of material to be moved each hour, its density (lb per cu. ft), the conveyor speed (ft per min), and a " material factor " (A, B or C) which depends on the material being handled.

Although Sandvik developed the nomogram for use with steel belt conveyors, it is suitable for other types of flat-belt conveyor.

Use the Nomogram like this:

To find the belt width recommended to carry 90 American tons (2,000 lb) per hr of a material weighing 60 lb per cu. ft at a speed of 200 ft per min and having a material factor C. Locate 90 on the D (capacity) scale and project a line through 60 on the adjacent E (volume weight) scale until it intercepts the F (capacity) scale. Draw a line from here through 200 on the G (belt speed) scale and extend it to the H (load) scale. From this point draw a line through the material factor blob C to scale J, to give the width of flat belt as 24 in.



STIFF MESH IN SHEET AND ROLL

The range of mesh materials available to design engineers has been increased now that high density polyethylene mesh has been introduced by the Expanded Metal Company, Caxton Street, London, SW1. Produced in roll or sheet form (similar to metal mesh), it is made from Rigidex polyethylene supplied by British Resin Products and has these advantages: it has a very low specific gravity (0·96) which makes it only one third the weight of a corresponding aluminium mesh, or less than one eighth the weight of mild steel. In all thicknesses, the mesh is flexible enough to be handled easily, while any thickness above $\frac{1}{8}$ in is stiff enough to be self-supporting.

The mesh has a comparatively high strength-to-weight ratio and is virtually indestructible. It is said to be resistant to water, sea-water, practically all chemicals, most oils, greases and solvents. Because of the inertness of the polyethylene from which it is made, very few substances will adhere to it, even temporarily. The mesh is thus easy to clean. In addition, it is available in several colours inherent in the polyethylene, and so does not need painting or finishing. It has outstanding electrical properties, the dielectric constant being 2·35 at 1 Mc/s and the power factor less than 0·0001 at 1 Mc/s. The mesh can be used at temperatures up to 100° C without significant distortion and so can be sterilised in boiling water.

Uses for the new mesh include: guards for electric motors operating in corrosive conditions; battery separators; grilles and screens in chemical plants and laboratories; filtration supports; garden furniture and interior decorative panels.

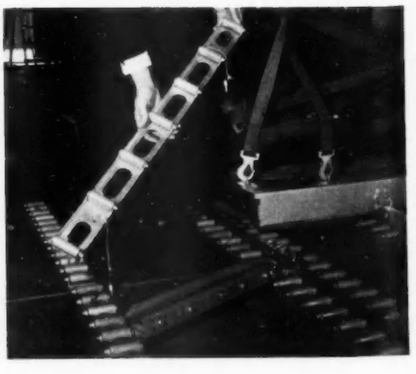
ROLLER CONVEYOR FOR ARGOSY AIRCRAFT

Armstrong Whitworth have developed a light-weight roller conveyor and pallet loading system for the Argosy freighter aircraft that is quick to assemble in the aircraft. Fittings pinned in the seat rails restrain the pallets against forward, lateral and upward flight accelerations.

The photograph shows the anchored pallet. One of the roller units in the foreground has been removed from the floor by removing the pip-pins. Transportable bridge sections compensate for slight differences between the height of the aircraft and the road truck, to which similar roller sections are fitted. In this way the entire payload (up to a maximum of 27,000 lb) can be loaded in about 12 min by four men working (without mechanical aid) from both ends of the hold (that is, two men at each end). For comparison, in the DC6C freighter (a converted airliner) which is loaded through a much smaller door in the fuselage side, it takes 6 men more than 2 hours to stow the full load. The economy in turnaround time using the new conveyor more than compensates therefore for any structure weight increase caused by these loading arrangements.

It was in January of this year that the first Argosy made its maiden flight at Bitteswell airfield. Some 350 hours of test flying have now been completed and today there are five Argosy's off the production line. The first three are fully instrumented for the flight tests necessary for certification. Handling trials over the full weight and c.g. range have been completed and detailed performance evaluation is now under way on the third aircraft.

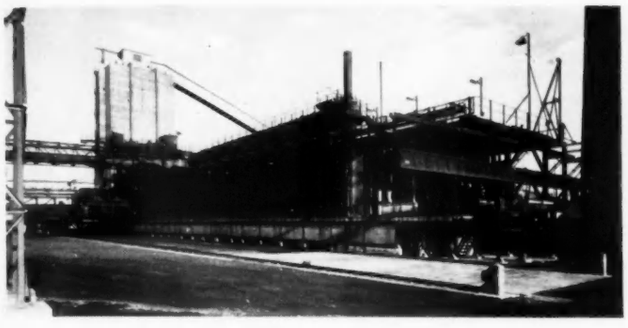
The main function of the Argosy is, of course, to carry freight, one of its main features being the use of full-width, side-hinged freight doors at the nose and tail of the fuselage. The floor of the hold is 4 ft above the ground for loading.



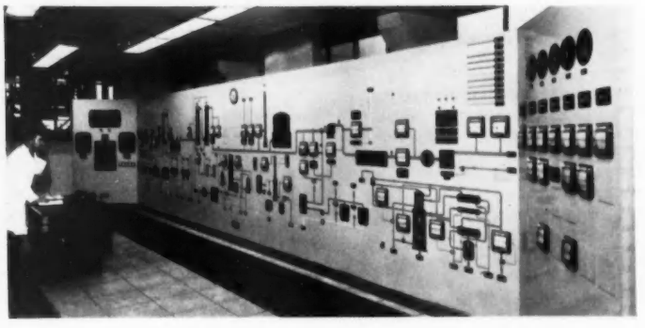
COKING AT THE PIT HEAD

Three coal mines, a washery and two batteries of coke ovens have been connected to form an operating unit at the new Murton plant of the Durham Division, National Coal Board. Coal will be drawn from three collieries—Murton, Eppleton and Elemore—through the new Hawthorn shaft, which is 22 ft diameter and 1,500 ft deep. It will be served by two electric automatic winders drawing from two levels, at 1,070 and 1,430 ft, and locomotive haulage will connect the shaft with the three collieries. Some 18 miles of underground roadways will have been driven by the date of commissioning of the new shaft, September 1959. Individual winding equipment will be retained at the collieries and will be used for man riding and for transporting supplies. The planned output of the Hawthorn shaft is 1·5 million tons of saleable coal a year, the highest output in Great Britain from a single shaft.

Coal raised at the Hawthorn shaft will be treated in a new washery having an hourly capacity of 750 tons, and capable of producing a range of sizes, the larger being for sale and the smaller, 1 in to 0 in, either for sale or delivery by conveyor to the coke oven blending bunkers.



Two batteries of Woodall-Duckham coke ovens receive their coal direct from a pithead coal preparation plant at Murton.



An outstanding feature of the plant is the series of control systems, which provide near-automation. This panel controls the by-product plant.

COKING

Built by the Woodall-Duckham Construction Company Limited, 63 Brompton Road, London, SW3, the coking plant consists of two batteries of 25 W-D Becker combination underjet coke ovens. Provision is made in the design for the addition of a third battery at a later date if required. The present plant will carbonise up to 1,000 tons of coal/day, and the yearly output of high grade metallurgical coke will be some 250,000 tons. Purified gas will be fed to the gas grid at a rate of 7½ million cu. ft per day, and the by-product plant will produce concentrated ammoniacal liquor, tar, and about 1 million gallons per year of crude benzole. An outstanding feature of the plant is the advanced system of centralised instrumentation. Six grades of coke are produced and loaded to road or rail vehicles as required. Provision is also made for stocking and reclaiming both coal and coke.

From the coal preparation plant the coal, ½ in to 0 in or 1 in to 0 in, is delivered at 520 tons per hour to a line of reinforced concrete bunkers, with eight compartments, each of 400 tons capacity. Bunker discharge is over constant weight feeders, which deliver coal at from 15 to 80 tons per hour to a 30 in belt conveyor Provision is also made for feeding blended coal reclaimed from stock on to this conveyor, and coke breeze can also be brought in from an adjacent breeze crushing and handling plant. Blended coal passes to a crusher house, with a swing hammer pulveriser, capable of reducing the coal at a rate of 80 tons per hour to 80 per cent through ⅛ in mesh. From the crusher the coal is taken on a 42 in belt to a transfer station. At the transfer station the coal can be fed to a hopper whence it passes to vehicles for transport to the stock heaps, or to the conveyor leading to the coke oven bunker. The crusher can be by-passed if required.

Coal is held for charging the ovens in a reinforced concrete bunker of 2,200 tons capacity, with a separate 700 ton compartment which can be used for test purposes. The ovens are charged by a portal type car, with four 17 ton hoppers, each fitted with an adjustable measuring device and an electric vibrator to facilitate discharging. A 60 ton weighbridge is provided for weighing the coal in the car before charging, and a self-landing and discharging hoist returns to the car coal withdrawn during levelling.

HEATING

The ovens, which are each 40 ft 9¾ in between doors, 13 ft high and 18 in average width, are designed for heating by coke oven gas, with provision for producer gas heating at a later date. When coke oven gas is used, the underjet system is employed, and one half of the regenerators are used to preheat the air. Automatic control of the valves at 30 min intervals changes the gas and air flows. When coke oven gas is employed for heating in the future, the regenerators will be used to preheat both the gas and air. Control of the ovens is from a control room at the bunker end of the battery.

A combined coke pusher, levelling and door handling machine is controlled by a W-D gamma interlock system in which a gamma-ray beam passes from the coke guide to the pusher machine through the space above the charge. This ensures that the charge cannot be pushed until both doors have been removed and the pusher is correctly aligned with the oven. It is claimed that this is the first application of this type of control to a coke pusher.

DISCHARGING

A40 ft long steel quenching car receives the hot coke and transfers it to the quenching station, which is of the recirculation type, with a 10,000 gallon overhead water tank. From this point the car is run to the 150 ft long inclined coke wharf, where it discharges its load. A 36 in conveyor takes the coke to the screening station. Here a comprehensive layout of conveyors, screens and coke cutting machines enables the run-of-oven coke to be sorted into six size grades and loaded into storage hoppers. A system of boom loaders enables the graded coke to be delivered to road or rail vehicles. Alternatively, it can pass to two weighing and bagging machines. Coke reclaimed from storage can also be taken into the grading plant, for despatch in the same way, and a take-off conveyor allows coke to be put into stock.

CONTROL

The outstanding feature of the Murton plant is the centralised control which provides a degree of near-automation higher, it is claimed, than has ever before been achieved in coke oven operation. The principal control equipment is that provided for the by-product and benzole plants. Designed by Woodall-Duckham and of Foxboro-Yoxall manufacture, a graphic panel 40 ft long provides minute-by-minute information on the flow of coke oven gas, producer gas, ammoniacal liquor, tar, benzole, wash oil, water, steam and air. Most of the plant is controlled from this central point.

PRESSURE VESSELS AND HEAT EXCHANGERS

A new factory for the production of pressure vessels and heat exchangers has been brought into operation by Steels Engineering Installations Limited, Crown Works, Sunderland. There are three main production bays, two of which run parallel while the third lies at right angles and across the end of the other two. The larger of the two parallel bays, which is 150 ft long and 40 ft wide, is designed for preparing plates, and in the adjacent bay, 150 ft by 30 ft, tube bundles and smaller parts for heat exchangers are assembled or fabricated. In the right angle bay, which is higher than the other two, assembly and testing are carried out.

Both the low bays are equipped with 10 ton overhead travelling cranes, the gantries being cantilevered into the high bay. An extended gantry at the opposite end of the plate preparation shop enables the crane to travel out over a steel stock area 60 ft × 40 ft. Jib cranes of 1½ tons capacity are provided in the parallel bays. Two 20 ton cranes serve the high bay, the gantry being cantilevered out at one end for loading finished products on to either road or rail vehicles.

A template shop and a gas fired stress-relieving furnace 54 ft by 23 ft adjoin the assembly bay. A dark room for dealing with X-ray film processing is also located at this point.

Machines of normal type installed in the plate preparation bay enable cutting, edge planing, edge setting and cylinder rolling to be carried out ready for assembly and welding. Of special interest is the pyramid type plate rolling machine, which will roll cylinders of unusually small diameters; there is, of course, no maximum size except that imposed by transport limitations. The plate rolling machine will, for example, roll ½ in thick, 10 ft wide stainless steel plate down to 18 in diameter, or 2 in by 5 ft 6 in mild steel to a minimum inside diameter of 2 ft 6 in.

Welding, which is carried out in the assembly bay, can be done by any of the three processes, submerged arc, open arc or inert gas shielded.

SPEEDIER CEMENT HANDLING

At the Erith North factory of Turners Asbestos Cement Company Limited cement handling has now been mechanised, resulting in an improvement in efficiency and factory amenities. Before the new development programme, cement was delivered in bags, transported by lighter from the Essex side of the river Thames, unloaded by cranes and mobile handling equipment into storage, and then moved manually to the process department as required.

In planning the reconstruction it was decided to use the same source of supply, and the cement is now transported in bulk in barges belonging to the Associated Portland Cement Manufacturers Limited, and transferred mechanically from the barges to the points of consumption. The barges of 320 tons capacity, are brought into the company's dock, 220 ft long and 80 ft wide, which communicates directly with the river, and positioned under a bucket elevator. The barges are fitted with aeration pads for bringing the cement to their mid-length, and from this point it is lifted to a hopper by means of an electrically-driven recirculatory drag scraper conveyor. Air and power for moving the cement within the barge are supplied from the handling plant pump room ashore.

UNLOADING

From the hopper the cement is lifted by a vertical, centrifugal discharge type bucket elevator suspended from a steel structure, and so counterbalanced as to compensate automatically for height variations in the barge due to tide and draught. Operating at a speed of 152 ft per min, the elevator has buckets of 720 cu. in capacity at 17 in intervals; it is driven from the top, and tensioned at the bottom. When not in use, the conveyor can be winched in to a parking position, leaving the berth clear except for the overhanging suspension structure.

A screw conveyor 18 in diameter and of 14 in pitch, running at 48 r.p.m., is flexibly connected to the bucket elevator and to a fixed screw conveyor in such a manner that cement can be passed ashore under all conditions of tide and draught. A certain amount of lateral freedom, to allow for barge movement due to wind or passing traffic, is provided for in the rear support of the swinging screw conveyor.

The fixed screw conveyor, which is of similar design to the swinging conveyor, delivers the cement to a Locker " Rotex " single deck screen, fitted with a 6 mesh, 19 gauge steel cloth, and then to a surge hopper and a Fuller-Kinyon powder pump; all this equipment is located in the pump room. A 7 in diameter asbestos cement pipe conveys the cement to a battery of four storage silos, electric remotely-controlled two-way valves being used to direct the flow to any particular silo. Asbestos cement piping has been used in preference to steel or cast iron because experience has shown it to have better resistance to the abrasive wear of air-borne cement.

To enable a barge to be unloaded well within an 8-hour shift, the rate of cement movement is 55 tons per hour, and this involves an air consumption of approximately 45,000 cu. ft per hour, the pressure being 20 lb per sq. in. A Hick Hargreaves rotary compressor is installed for this duty, and a centrifugal collector, followed by a fabric filter, cleans the conveyance air after it is released from the silos. Provision is made for periodical return of the reclaimed cement from the air cleaning equipment to the silos.

STORAGE AND DISPOSAL

The four welded steel silos, each 22 ft diameter and of 300 tons capacity, are installed adjacent to the four production machines they serve, and the conveyance pipe makes a tangential entry into the top of each silo at a height of 55 ft. Air jets are arranged in the lower part of the conical section of each silo, to prevent bridging of the contents over the opening. Diaphragm type contents level switches are fitted at the high levels and electronic probe type switches are mounted at the intermediate and low levels. Provision is made for both filling the silos from and emptying them into, pressurised road vehicles in case of emergency.

Cement is extracted from the base of each silo through a shut off slide gate and a rotary feed valve, and a 54 ft long 9 in diameter screw conveyor of 10 in pitch transfers it as required for production to a 3,000 lb hopper scale; it is moved at a rate of 12 tons per hour. The weight indicators of the scales are mounted near the process control stations, and they are fitted with adjustable cut-off controls to enable the batch to be varied. Electric interlocking prevents the scale hoppers from being discharged until correct weight is reached, or from being refilled before it is completely empty. Automatic continuous paper printing recorders are incorporated in the scale dial mechanism.

All operations, with the exception of the control of the batch weighers, are controlled from a panel mounted in the pump room. Interlocking of the motor controls prevents wrong sequence operation, and a mimic diagram shows the units in operation and the height of the silo contents.

The design and erection of the plant were carried out under the supervision of the chief engineer of Turners Asbestos Cement Company Limited, Mr. L. D. Norton, who provided the information on which this article is based.

Cement arriving in 320 ton barges at the Erith North factory of Turners Asbestos Cement Company Limited is unloaded by a fully mechanised plant.

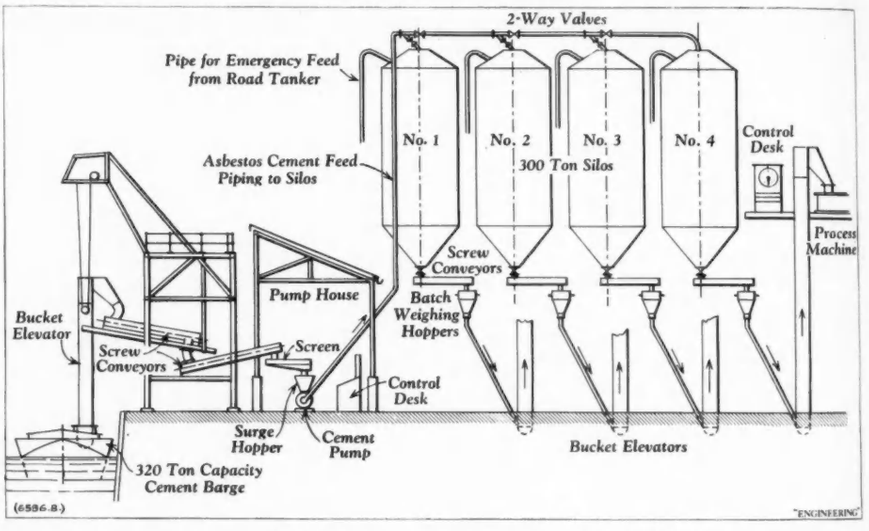


Diagram of the plant layout. All handling is mechanical, and control is interlocked and centralised.

MECHANICAL HANDLING AT VAUXHALL MOTORS

When a firm has 15 types of electric truck in almost continuous operation, the servicing of traction batteries presents quite a problem, and it is interesting to see how it has been solved to give the most effective productive working time possible. This has been done at the Vauxhall Motors car factory at Luton and at their new Bedford truck factory at Dunstable.

Vauxhall Motors use electric fork lift trucks for most of the bulk handling of components for manufacture, raw material and spare parts. Their Luton plant is divided into eight areas, with a number of trucks operating within each specific area. The areas have a charging and routine servicing station, and the number of charging points varies between 10 and 25.

The productive working schedule of the trucks is such that it is necessary for them to be charged only once a shift. This is an important point in this factory, where continuous operation of the production lines depends to a very large extent on the efficient operation of the trucks to feed the line and move finished sub-assemblies to other sections. To ensure that a truck returns on time for recharging, the date and time of the next charge is chalked on a specially painted black square on the masts of the Stacatrucs and somewhere (easily seen) on the bodies of the other types of truck.

When due for a recharge, a truck is driven as near as possible to a charger and the battery is removed by a 2 ton King overhead hoist and deposited on the charging platform. A newly charged battery is then inserted in the truck, and after a quick checkover by the battery maintenance staff, is ready to resume work. By interchanging batteries in this way, the highest number of working hours possible is attained. The high capacity of the Crompton Parkinson lead-acid traction cells keeps to a minimum the unproductive running time from work place to charger.

In the Company's works and stores at Luton and Dunstable there are in constant use eight types of tractor and seven types of fork lift truck, totalling 500 power vehicles in all.

Operation and Maintenance

MODERNISING A SMALL FACTORY

Until 1955 the engineering factory of the United States Metallic Packing Company Limited, at Bradford, was driven by a Cole, Marchent and Morley compound steam engine of 160 h.p. Electrification was decided upon in that year, and the work has now been completed.

Covering 2¼ acres, the works manufactures metallic packing for steam engines, centrifugal pumps, gas and diesel engine piston rods, steam traps and a range of pneumatic and hydraulic power cylinders. Most of the plant is of the type generally associated with light engineering, including conventional machines such as lathes, radial drillers, borers and grinders; some woodworking machinery is also installed. All the machinery was originally driven by belting from overhead lineshafts and countershafts with the usual type of fast and loose pulleys and belt striking gear. Electrical services were powered from two belt driven d.c. generators.

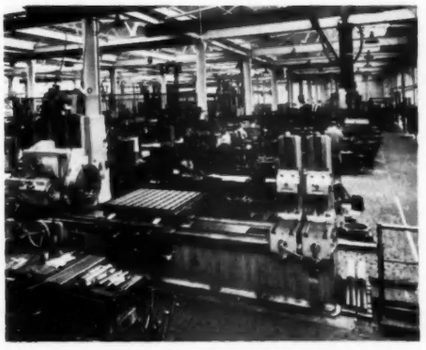
Before deciding on the individual h.p. requirements of the electrical drives, representative machines were fitted with a test motor, and on load wattmeter readings were taken by engineers from Crompton Parkinson Limited, Aldwych, London, WC2. Power estimations proved to be entirely correct.

In June 1955 a start was made by running cables from a 1,000 amp oil circuit breaker to four main distribution points in the factory, the cables being supplied, as were all the motors powering the machines, by Crompton Parkinson. Groups of new motors—ranging in size from ½ h.p. for small grinders to 40 h.p. slip ring machines for compressor drives—were bolted in position ready for the changeover, the operation being so planned that when the change from shafting to motor V-belt drive was made, normal production was virtually uninterrupted. In a few cases, because of the constructional details of older machines, direct motorisation was not practicable. For these machines a part of the original lineshafting was retained, and the driving motor is mounted overhead, adjacent to the lineshaft pulley. Nearly 150 motors, of both squirrel cage and slip ring types, are now in use, the total h.p. being about 900.

An outstanding effect of the motorisation is the flexibility of the shop; it is now much more economic to run a few machines outside normal working hours if required. About 15 per cent speed loss due to belt slip has been eliminated, and the machines are now operated at speeds and feeds much nearer to the theoretically correct figures. In addition, the natural lighting of the shop has been improved with the elimination of the mass of overhead belting.

Before—the machine shop of the United States Metallic Packing Company when it was lineshaft driven.

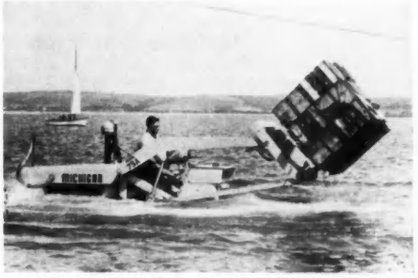
After—the same shop with individual drives from Crompton Parkinson motors.



NO PORT FACILITIES

In many parts of the world it is necessary to load and unload lighters from a beach, because port facilities do not exist. Michigan (Great Britain) Limited, P.O. Box No. 3, Camberley, Surrey, have modified their standard four wheel drive, rubber tyred model 75A tractor to operate under these conditions.

The fitting of a forklift attachment in place of the normal shovel, and "wadeproofing" of the mechanical equipment, make it possible for the tractor to operate in up to 6 ft of water. It can lift 4,000 lb, and with a travelling speed of 27 m.p.h., can run off the foreshore to transport its load in the same way as a normal lorry.



Marketing

Not Restrictive

The removal of several trade agreements from the Register of Restrictive Trading Agreements suggests that the Restrictive Practices Court are taking a realistic commercial attitude to such arrangements. They included agreements between members of the Water-Tube Boilermakers' Association, the Pit Tub and Mine Car Manufacturers' Association, 12 manufacturers of sodium hypochlorite solution, the British Constructional Steelwork Association, the Central Electricity Generating Board and the Ornamental Pottery Association.

In the case of the last four the reason given was that the particulars of the agreements appeared to the Board of Trade "to be of no substantial economic significance." The decision of the court in favour of the agreement between members of the Water-Tube Boilermakers' Association drew the comment by the association's chairman that it ensured there would be "no deterioration in the standards which the industry has set itself."

European Market Study

A new international drive in the field of market research is likely to result from the Conference on European Market Research organised in Paris by the OEEC European Productivity Agency at the end of June. Some 150 representatives of market research services, market research firms, public statistical services, public bodies concerned with external trade and professional organisations discussed the methods to be employed for market research on a European scale.

Among recommendations approved, the participants asked that a major effort should be made to ensure a wide circulation among market research specialists of the existing statistics and studies. All professional organisations have an essential role to play in this field, particularly in regard to small and medium undertakings. The Methods Commission proposed that results of research not of a confidential nature should be made generally available, and that a body should be set up to centralise research results on the European scale. Dr. Alexander King, deputy director of EPA, emphasised the role which the agency would play in the exchange of information and experience.

China at Leipzig

For the first time the Leipzig Autumn Fair (30 August to 6 September) will include exhibits from the Chinese People's Republic. Consumer goods, such as silks, porcelain, objects of folk art together with foodstuffs and allied products will constitute the mainstay of the Chinese exhibit which will take up 10,750 sq. ft. This is as much space as has been occupied by the Soviet Union and will give the outside world a clearer idea of what China has to export to pay for the engineering products she is so keen to import.

The largest space has been taken up by Czechoslovakia, whose seven foreign trade corporations will display consumer goods, vehicles and engineering products. Altogether some 6,500 participants, from 45 countries, are exhibiting in an area of 1·2 million sq. ft.

Prime Movers

Substantial export orders have been reported recently by British manufacturers of electric motors and diesel engines. Newman Industries Limited of Yate, Bristol, have begun to reap the reward for having developed a special range of light industrial and domestic motors to cater for the requirements of North American users. An order for 500 units was booked at the beginning of the month by their United States sales office for the eastern region (at Newark). The motors, which are of the totally enclosed, fan-cooled ½ to 2 h.p. type, will be used for driving

fans in car washery plants. Another order for 300 motors has been received from the Peerless Pump Division of the Food, Machinery and Chemical Corporation in Los Angeles.

Perkins Engines Limited have begun to penetrate the west German market. They have received "a substantial order" for their Four 270D engine from the largest manufacturer of combine harvesters in Western Europe, Geb. Claas, Maschienenfabrik, GmbH, of Harsewinkel. This engine is standard equipment in the "Europa" and "Hercules" self-propelled combine harvesters. The successes of both Newman Industries and Perkins Engines in such fiercely competitive markets is a good omen for British engineering exports and a tribute to those companies' aggressive selling.

Order Book

The booking of £500,000 worth of orders by a firm employing only 50 people in all is an unusual feat. This was done by William Boby and Company Limited, of Rickmansworth, for a range of purification plant for water and other liquids. Bobys have carried out pioneer work in cooperation with Dutch and other foreign research scientists into the purification of liquids by electrical processes. An agreement has been concluded recently with the American Machine and Foundry Corporation of the United States to market the Boby plant in the United States, Canada and other countries in the Western Hemisphere, excluding British territories.

The firm, which is headed by Mr. Michael Boby, who is the grandson of the founder, are entering a period of rapid expansion. They are doubling their design staff and building new accommodation. Boby's electrodialysis desalting "stack" installed at Tobruk is producing 1,200 gallons of fresh water daily from brackish desert wells. The Air Ministry have ordered two complete plants.

Selling Arms

The sale of munitions and other military equipment to foreign Governments by the Ministry of Supply averaged £45 million a year during the four years 1954-55 to 1957-58. These were Government-to-Government sales and did not include direct exports by the manufacturers of the equipment. For example, in 1957 the value of the Ministry's sales of military aircraft, including air and ground control equipment, amounted to £9·2 million, whereas United Kingdom exports totalled £61·4 million.

The second report from the Select Committee on Estimates entitled "Sale of Military Equipment Abroad" (HMSO, price 9*s*) reviews the whole field and the machinery of control operated by the Ministry of Supply. The committee are satisfied that the Ministry and the Service Departments "appreciate the economic and strategic advantages of the sale to foreign countries of British military equipment and stores," but found that this appreciation "has not always been fully translated into the determined effort necessary for effective sales promotion." Their recommendations are designed to effect an improvement, so that the United Kingdom retains her share of the world market in arms which is "increasing year by year and is becoming highly competitive." Most of the recommendations relate to changes in the organisation of the Ministry and Service Departments and to the sales promotion functions of Service Attachés abroad.

At Home

POST-AND-BEAM HOUSES

Canada has few regional styles of modern building. In earlier days different regions, for various reasons, did develop special local building techniques such as the use of short cedar log wall construction in the Ottawa Valley, but in recent years the only really significant local trend in building has been the relatively rapid development of the post-and-beam system of construction, particularly for houses in the Vancouver area of British Columbia.

In keeping with its work in maintaining close touch with all modern building techniques in Canada, the Division of Building Research of the Canadian National Research Council recently arranged for a field study of post-and-beam construction in the Vancouver area. This work was arranged in cooperation with the School of Architecture of the University of British Columbia, the site study being carried out by Professor V. F. Lyman. The project is typical of one branch of building research to which the Division is giving increasing attention.

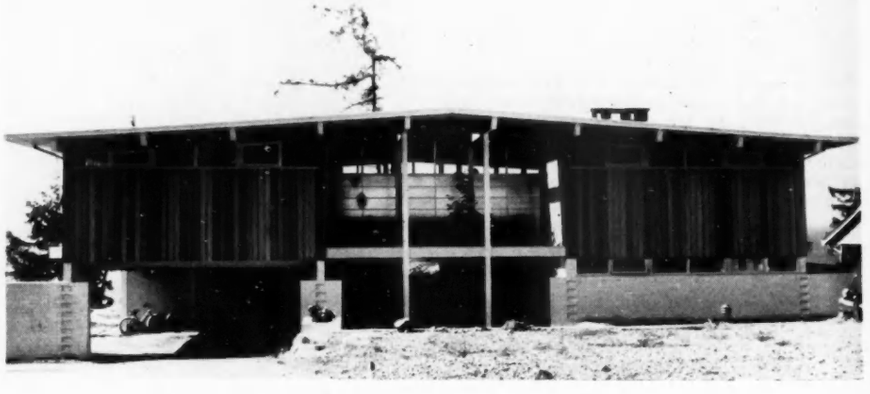
Wood post-and-beam construction systems consist of beams spaced from 3 to 12 or more feet apart, supported by isolated columns—the posts. Tongued-and-grooved planking, 2 or 3 in thick, usually spans between the beams to form the floor or roof construction, though joists or prefabricated panels are also frequently used instead of planks. Siding, sheathing, or solid panels take care of necessary bracing, sometimes with the addition of rigid connections between the post-and-beam systems. The walls carry no load and this has permitted the architects to use full glass panels in many cases in keeping with this trend of modern architecture. There are today about 2,000 buildings, almost all modern residences, in the Vancouver area of the post-and-beam type and a selection made from these houses was studied in some detail.

In Greater Vancouver the first buildings erected in this way were summer houses in West Vancouver, where the southern slopes of the mountains, terminating in beaches, proved ideal locations for weekend and summer residences. Local stone and unfinished cedar were used for building materials, giving the buildings a rustic quality. For this reason the first post-and-beam constructions in Vancouver were usually associated with naturally finished, wood-covered houses. Subsequently the basic design system has been used with a variety of exterior finishes and wall systems, providing a variety of house designs all of the same basic type.

During the field survey four main types were noted. The first group was that using solid wood for both posts and beams. The second and third groups used forms of laminated timber while the fourth subdivision included houses built with prefabricated plywood box beams, and, to some extent, prefabricated wall panels and laminated posts.

The field survey confirmed the obvious advantages of this method of construction, particularly in giving architects much greater freedom for house design than does conventional construction. At the same time some serious disadvantages also came to light. Many of these related to construction rather than to design. For example, the rough "carpentry" is very often exposed and has to serve as unsatisfactory "finished carpentry" if the heel marks of workmen, for example, form an unintentional pattern on the exposed wood. Many of the apparent economic advantages of post-and-beam framing are lost in the expense of heavier timber, more expensive finishing material and the necessary protection of all wood during construction. Wind bracing is always necessary and its provision in design sometimes constitutes a problem. The other advantages of reduced building height are off-set by difficulties with the installation of mechanical and electrical services, since it is very difficult to conceal these in a true post-and-beam house.

Despite these and other disadvantages, post-and-beam construction is certainly being widely used and its development on Canada's Pacific Coast is being closely followed by the Division of Building Research. The results of Professor Lyman's survey have been incorporated in Technical Paper No. 70 published by the Division. Copies of this report, which is illustrated with photographs and drawings, may be obtained on application to the Division in Ottawa, at a cost of 50 cents per copy.



A typical post-and-beam house in West Vancouver, Canada.

ENGINEERING

Published every Friday by ENGINEERING LTD. at 36 Bedford Street, London, WC2.
Telephone: Temple Bar 3663.
Telegrams: Engineering Lesquare London.

CHAIRMAN: J. A. Dixon, M.A., A.M.I.Mech.E.
EDITOR: F. B. Roberts, M.B.E., M.I.Mech.E.
DEPUTY EDITORS: D. Fisher, Ph.D., B.Sc., A.M.I.C.E., A.M.I.Mech.E.
E. P. Ward, M.A., A.M.I.Mech.E.
ASSISTANT EDITORS:
Design: W. L. Morse, B.Sc. (Eng.) A.M.I.Mech.E., A.F.R.Ae.S., A.F.I.A.S.
Metals and Materials: D. C. E. Gribble, B.Sc.
New Plant and Equipment: A. A. H. Scott, B.Sc., A.M.I.Mech.E.
Parliament and Institutions: J. E. Dodsworth.
Research and Development: R. A. Coffee, D.I.C., A.M.Brit.I.R.E.
MIDLANDS CORRESPONDENT: W. K. V. Gale.
EDITORIAL DESIGNER: J. T. Godfrey.
SUBSCRIPTION MANAGER: G. A. Roberts.
ADVERTISEMENT MANAGER: G. H. Dixon.

Annual subscription rates: Inland and abroad £5 10*s* (Canada, £5 5*s*). Three months 27*s* 6*d* all countries. Single copies, 2*s* 7*d* post free.

ENGINEERING INFORMATION SERVICE:
Assistance is available from Engineering Information Service in obtaining information, and in locating sources of information, both technical and commercial. EIS deals, for example, with names of makers and suppliers of plant and equipment, technical data on design, markets for engineering products and the compilation of references to information on specific topics. Inquiries should be addressed to Engineering Information Service, 36 Bedford Street, London, WC2.

FOUR TRANSPORT PAPERS FROM THE BRITISH ASSOCIATION MEETING

At the British Association Meeting at York, the Engineering Section took Transport and Communications for its main discussion theme. Four of the papers are published in the following pages: three on road subjects and one on VTOL (vertical take-off and landing) aircraft. The presidential address by Sir Ewart Smith appeared in last week's issue (4 September). Next week, 18 September, ENGINEERING will publish the remaining transport papers, all of them on railway topics. A paper on High-Speed Photographic Analysis of Blasting, by E. M. Patterson, will be published in the journal later. Extra copies of all these issues are available from the Subscription Manager, as explained in the notes at the foot of page 192.

The five railway papers for next week are: Railways, Roads and the Public Good, by Sir Reginald Wilson; The Place of the Diesel Locomotive, by E. S. Cox; Railway Electrification Programme, by S. B. Warder; Computers in Transport, by G. H. Hinds; and Future of Freight by Rail, by G. F. Fiennes.

BUILDING THE LONDON-BIRMINGHAM MOTORWAY

By W. KIRBY LAING, M.A., M.I.C.E.

Chairman, John Laing and Son Limited

John Laing and Son Limited won the four contracts for the construction of the London to Birmingham motorway with fixed price tenders. A period of 19 months was allowed for the work that involved the excavation of 15 million tons of earth, laying the 55 miles of dual carriages and building 132 bridges and 90 more culverts. Key staff were brought from other contracts and 5,000 men recruited; plant developing 80,000 h.p. was distributed along the route. At peak periods 30,000 tons of materials were required each day. The motorway will be completed in October.

Fig. 1 A completed section of the road.

FROM the highway engineer's point of view we are living in a very exciting period because, for the first time in more than a century and possibly since the Romans, an entirely new road system has been planned and is being constructed in this country. Previously, few entirely new roads have been laid out in this country other than the series of so-called by-passes which were constructed during the 1930's. Prior to that date any road construction which was undertaken was largely improving existing roads. This applied even to the works of such well known engineers as Telford who carried out a tremendous amount of work in connection with the improvement of the British roadway system.

The present motorway programme envisages the construction of high-speed roads which will link the industrial areas of the country with either London or the various ports and it is well to consider in the first place how the proposed motorway system will fit into the existing road pattern.

A map of the country—Fig. 2—suggests that we are very well served by roads in all areas, but in a consideration of this sort one needs only to think of the six main roads radiating from London to see how inadequately these serve the needs of the country. A1, the Great North Road, links London with the north-east coast and eastern Scotland. A2, links London with the Medway towns and the Kent coast ports on the English Channel. A3, the Portsmouth road, gives access between London and the Naval Dockyard in Portsmouth. A4, the Bath road, is the only means of connection between Avon docks and London. A5, the Holyhead road, links southern Lancashire and the industrial Midlands with London in an inadequate way, due to its narrow width and heavy gradients; and A6 is the main link between the heavily industrialised areas of Staffordshire, Lancashire and western Scotland.

On to this existing road system are now to be superimposed the motorways. Firstly, there will be the London to Birmingham motorway with its eventual connection to Yorkshire at Doncaster; secondly, the motorway will proceed northwards to Preston and southwards to Bristol and South Wales. In addition, there are the extensive improvements being made to the road facilities around the Medway towns and eastern Kent, and to the west from London.

These motorways will be designed to allow traffic to travel on them at speeds up to 70 m.p.h. and will have dual carriageways, each 36 ft wide and separated by a central reserve which will be planted with grass or shrubs. On either side will be a hard shoulder on to which vehicles can turn in the event of a breakdown so as not to interfere with the flow of traffic on the carriageways themselves. They will have very limited access and no cross roads, so that once vehicles have entered there should be no need for them to reduce speed.

The part of the motorway with which this paper is concerned is 55 miles long and stretches from the outskirts of Luton to a point on the A45 just outside Dunchurch, adjacent to Rugby (Fig. 3). The contract for the construction was let by the Ministry of Transport and Civil Aviation, the design having been undertaken by Sir Owen Williams and Partners, consulting engineers, of London. Under the contract my Company has undertaken to construct these 55 miles of road in a period of 19 months on a firm price basis, that is, no alterations in price are allowed to cover variations in costs of materials or labour, although a remeasurement of the actual quantities of work involved will take place at the end of the contract.

PLANNING

As can be imagined, to undertake a contract of this magnitude, involving as it does a total of some £17 million and the construction of

Paper entitled "The London-Birmingham Motorway" read before the Engineering Section of the British Association at York, September, 1959.

Fig. 2 The motorways in relation to the major trunk roads.

132 bridges of varying sizes, together with 90 culverts, has involved a great deal of planning and organisational work, not only in the design stages but throughout the construction period.

The consulting engineers started their survey of the route in 1951 but authority to proceed with the actual design of the road was not given until 1955. Two years were spent on the design and tenders were invited from contractors early in November 1957, to be submitted to the Ministry in January 1958.

At the time of tendering, the work was divided into four contracts, three of these contracts being approximately 12 miles in length, the fourth 15 miles long. This subdivision was somewhat arbitrary but decided mainly by the nature of the terrain through which the road passed. In submitting their tenders contractors could bid for one or more sections. Tenders also had to be submitted on two bases: (1) involving two summers for the work and the whole project to be completed in 19 months; (2) in which three summers would be involved and the whole completed in 31 months. In addition, a further subdivision was required as tenders could be submitted as a firm price or with variations for cost of materials and wages. In effect, this meant that if a company was tendering for the whole road 16 separate tenders were required.

My own company put in tenders for each of the four sections of the contract and priced the 19 months period on a firm basis, but we decided that we could not foresee sufficient stability in the market to enable us to take the same risk for the 31 months contract, and we therefore priced this on the basis of a variation clause for materials and labour. In the event we were awarded the contract for the entire road on the basis of our tender for the 19 months period and acceptance was given on 20 January, 1958, with work to start on 24 March of that year and to be completed at the end of October, 1959.

From these dates it will be seen that we had only two months in which to prepare our tenders and a further two months in which to undertake all our detail planning after the contract was awarded. Tenders of this magnitude call for a great deal of work and 24 highly-skilled people were employed directly on their preparation. Approximately half this number belonged to our estimating department and the remainder from different sections of the business—specialists in planning and progressing, plant, soil mechanics, personnel, catering and welfare, and so on.

Because of the large number of individual structures that are involved (as I said earlier, there are 132 bridges of various sizes and 90 culverts, some of these culverts being up to 16 ft in width so that they are virtually bridges in themselves) a great deal of planning work had to be undertaken at the tender stage, deciding what was the correct order in which to carry out the different sections, where personnel would be obtained and how the contract would be staffed. Also to be taken into consideration was the amount of mechanical plant required and we had to decide how much of this could be supplied from our own resources and how much would have to be hired, or even whether certain proportions of the work would have to be carried out on a sub-contract basis, so making use of the facilities available in other parts of the industry.

After the acceptance of our tender two months were allowed for the finalising of our programme and during this period very many people were involved in a great amount of detail work. This applied particularly to our engineers who had to survey the whole line of the road, because in the tender documents we were only provided with levels on the centre line of the road itself. We had, therefore, to take levels along the two outer edges of the roadway and assess the total amount of excavation required and prepare plans which are termed " mass haul " diagrams, indicating where material had to be excavated and to what points it had to be taken, either for forming embankments or for carting away from the site altogether. Up to 100 engineers were involved in this work, over half of them operating in the field, the remainder documenting the information obtained by their colleagues on the site.

Another duty of these engineers was the acquisitition of land for our offices and stores depots, together with land on which to place our temporary dumps of topsoil that would later be used for covering the embankments or cuttings. The offices had a floor area of 40,000 sq. ft so that the land required for them covered several acres.

Other aspects which had to be dealt with at this stage were the arrangements for the provision of the necessary machinery. This contract is one of the most highly mechanised civil engineering projects that has been undertaken in Great Britain. In the summer of 1958 the machinery employed developed 80,000 h.p., equivalent to 20 h.p. per man employed on the contract. The plant included 72 scrapers, either hauled by crawler or rubber-tyred tractors and 150 mechanical excavators of various sizes, the largest being capable of digging 3 tons at one movement of their buckets.

We also had to make arrangements for recruiting 5,000 men. In this our personnel department worked in very close collaboration with the local trade union offices and those of the Ministry of Labour and National Service, and it was found that while many of the men could be recruited locally, a large number had to be brought in from distant areas, and we therefore had to arrange for hostels to be available in which these men could live for the duration of the contract. These hostels were found in various towns adjacent to the line of the road, and in most cases men did not have to travel more than 30 miles each way to and from their work. In addition our own key men, amounting to about 25 per cent of the labour force, had to be transferred from their existing work, entailing organisational changes throughout the company.

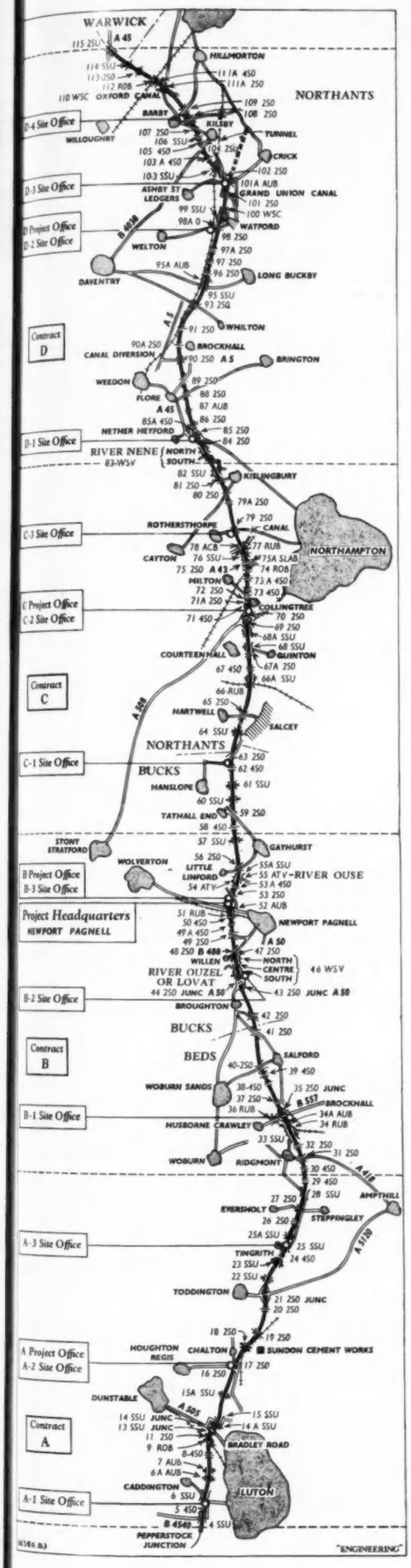
Besides machinery and men, supplies of the various materials had to be provided. At the peak period of the two summers, material was arriving at the rate of 30,000 tons daily. A few typical items were:—

2,500,000 tons of ballast for concrete. This is equivalent to 5,000 tons per day for the whole duration of the job, that is 1,000 lorry loads per day.

13,000 tons of steel for reinforcing the concrete.

5,000,000 gallons of diesel oil for running the machinery.

400,000 tons of asphalt to provide the wearing surface on which the traffic woul drun. And 130 miles of fencing.



Orders had to be placed with the various suppliers and these orders had to be phased so as to provide the material at the time it was required on the different parts of the job. As far as the steel was concerned there was no great difficulty because of the somewhat easier supply conditions prevailing in the steel industry in 1958.

For the diesel oil we were able to arrange with two major oil companies to set up distribution points along the line of the road and with their own tankers to deliver direct into our various machines. This meant that the machines themselves did not have to leave their work but were serviced on the actual job, so ensuring that they were available for the maximum number of hours possible during the working day.

As much of the machinery was required for only one summer and was of a very specialised nature it was decided to sub-let about 45 per cent of the earthworks and 35 per cent of the bridges (half of this number being undertaken by our associated company Holloways Holdings (London) Limited. In this way full advantage could be taken of plant already available in the country.

In the end our programme showed:

(*a*) Earthworks, except for diversions and railway over-bridges, to be complete by 31 December 1958.

(*b*) All culverts and under-bridges to be completed before the earthworks were commenced in the area.

(*c*) All major road bridges over the motorway to be completed to allow diversion of traffic over them by 31 December 1958.

In the event each of these targets was virtually achieved in spite of the phenomenally bad weather in 1958.

ORGANISATION

As the contract documents had been provided in the form of four separate contracts, and also in view of the fact that the consulting engineer had set up his own organisation to deal with the project on the basis of the same four contracts, we decided to divide our own management in the same way.

We therefore arranged for a headquarters staff working under a project general manager who had his headquarters alongside those of the chief resident engineer at Newport Pagnell. This headquarters staff was responsible for overall supervision, the measurement of our work for payment each month, ordering of materials, and accounts for materials received.

Under the project general manager were four project managers, each responsible for one section of the main contract. These project managers had their own staff working under them and their various projects were subdivided under a number of contract managers each of whom was responsible for approximately four miles of road. The lines of responsibility are shown in Fig. 5. In this way, each of these contract managers was dealing with a contract of a value of approximately £1 million. These main contracts were further subdivided depending on the work to be undertaken in a particular area. Thus each bridge or culvert became a contract on its own, supervised by a general foreman, and the intervening lengths of roadway were the responsibility of separate supervisory staff.

Fig. 3 The London to Birmingham motorway—which is the southern section of the London to Yorkshire motorway—showing the location of bridges and main contract offices.

SSO = *Single Span Overbridge*
2SO = *2-Span Overbridge*
4SO = *4-Span Overbridge*
SSU = *Single Span Underbridge*
2SU = *2-Span Underbridge*
AUB = *Arch Underbridge*
ATV = *Arch Type Viaduct*
WSV = *Wall and Slab Viaduct*
ACB = *Arch Canal Bridge*
WSC = *Wall and Slab Canal Bridge*
ROB = *Railway Overbridge*
RUB = *Railway Underbridge*

The main difficulty was that each of the 14 main contracts had to be started on one particular day, 24 March 1958. While my company is used to organising many contracts of this size or even larger, yet to have to start 14 such very large contracts at one time did pose many problems for us.

On such a widespread project, good communications are vital. In the first place project headquarters were provided with telephones, teleprinter and radio channels. The teleprinter gave access to our head office and plant depot and also with many materials suppliers. Radio also gave access to head office and, on separate channels, to each of the project managers. These in turn had their own radio channels which allowed them to be in touch with their various foremen and even some of the larger machines.

The project general manager has been using a helicopter, particularly during summer months. The value of this machine has been very great as it enabled the whole job to be viewed in two hours—by road it would take a week and even then the job could not be seen as an entity.

Besides these means, many Land Rovers and Austin Gypsies have been in use, over 70 of these vehicles being at the disposal of the staff so that they can readily reach the most inaccessible parts of the contract.

PAVING CONSTRUCTION

As will be seen from Fig. 4 each of the 36 ft wide carriageways is built up of a 6 in layer of granular fill followed by 14 in of very lean concrete, on top of which is placed 2½ in of asphalt base with a final layer of asphalt wearing course 1½ in thick. The whole of the formation is contained within two very strong concrete kerbs described as marginal haunches which finish flush with the wearing surface of the road and are finished with an intensely white concrete formed of titanium oxide so as to mark the edge of the running surface of the roadway itself.

Outside the nearside marginal haunch is a hard shoulder 8 ft wide formed of a loamy gravel which it is expected will grow grass and be sufficiently firm to allow vehicles to pull on to it in an emergency.

The lean concrete base course is laid in two layers each 7 in thick formed of concrete mixed in the proportion of approximately 18 : 1 of ballast to cement and each layer is rolled with an ordinary tandem-wheeled 10 ton roller until it is completely compacted. The reason for laying this concrete in two layers is that it has been found that it is impossible to compact the full 14 in in one layer, but by placing the concrete by a machine similar to that used for spreading asphalt or tarmacadam, a very hard foundation is formed for the roadway. This concrete has been used by our construction vehicles for many months without the protection of the asphalt wearing surface and has stood up very well indeed to the heavy traffic it has been carrying, so that by the time the wearing course is applied a very robust road will result.

One of the main features of a long road is how to provide adequate drainage, not only for the rain falling on the road itself but also to prevent percolation of water from the adjoining land. For the majority of its length this road has a crossfall, either over the individual carriageways or, where there is super-elevation on curves, over the total width of both carriageways. In all cases drainage to nearby streams is provided at the low side of the carriageway but, in addition, drains are made at the foot of all cuttings and embankments with cut-off drains at the top of cuttings. The central reserve, being enclosed by the concrete haunches, was a potential catchment area and this has been drained separately.

A major problem during construction has been that of access. It has been surprising how often

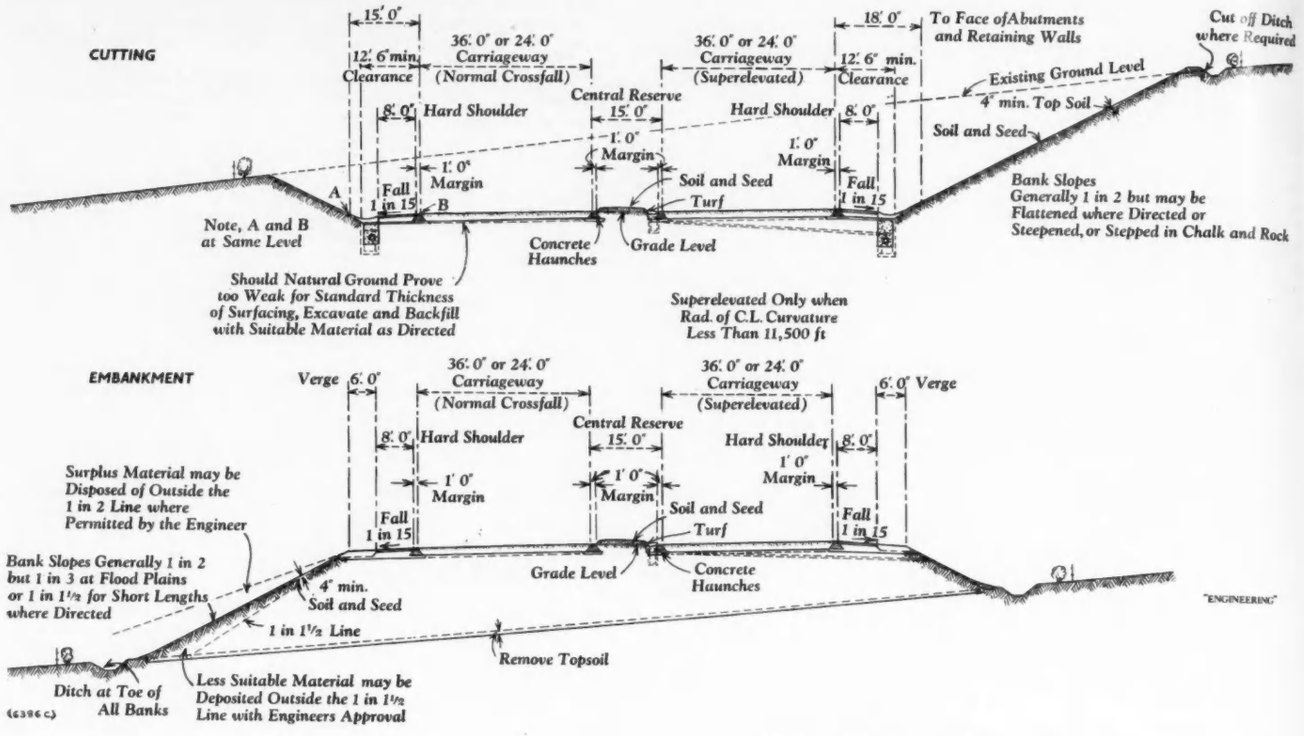

CUTTING
15' 0"
12' 6" min. Clearance
36' 0" or 24' 0" Carriageway (Normal Crossfall)
36' 0" or 24' 0" Carriageway (Superelevated)
18' 0"
12' 6" min. Clearance
To Face of Abutments and Retaining Walls
Cut off Ditch where Required
Existing Ground Level
4" min. Top Soil
Soil and Seed
8' 0" Hard Shoulder
Central Reserve 15' 0"
Hard Shoulder 8' 0"
1' 0" Margin
1' 0" Margin
1' 0" Margin
Fall 1 in 15
Fall 1 in 15
A
B
Soil and Seed
Turf
Bank Slopes Generally 1 in 2 but may be Flattened where Directed or Steepened, or Stepped in Chalk and Rock
Note, A and B at Same Level
Concrete Haunches
Grade Level
Should Natural Ground Prove too Weak for Standard Thickness of Surfacing, Excavate and Backfill with Suitable Material as Directed
Superelevated Only when Rad. of C.L. Curvature Less Than 11,500 ft
EMBANKMENT
Verge 6' 0"
36' 0" or 24' 0" Carriageway (Normal Crossfall)
36' 0" or 24' 0" Carriageway (Superelevated)
6' 0" Verge
8' 0" Hard Shoulder
Central Reserve 15' 0"
Hard Shoulder 8' 0"
1' 0" Margin
1' 0" Margin
1' 0" Margin
Surplus Material may be Disposed of Outside the 1 in 2 Line where Permitted by the Engineer
Fall 1 in 15
Fall 1 in 15
Soil and Seed
Turf
Bank Slopes Generally 1 in 2 but 1 in 3 at Flood Plains or 1 in 1½ for Short Lengths where Directed
Grade Level
Concrete Haunches
4" min. Soil and Seed
1 in 1½ Line
Remove Topsoil
Ditch at Toe of All Banks
Less Suitable Material may be Deposited Outside the 1 in 1½ Line with Engineers Approval
(6396C)
"ENGINEERING"

Fig. 4 (above) Typical cross sections of the motorway.

Fig. 5 (right) Management organisation chart.

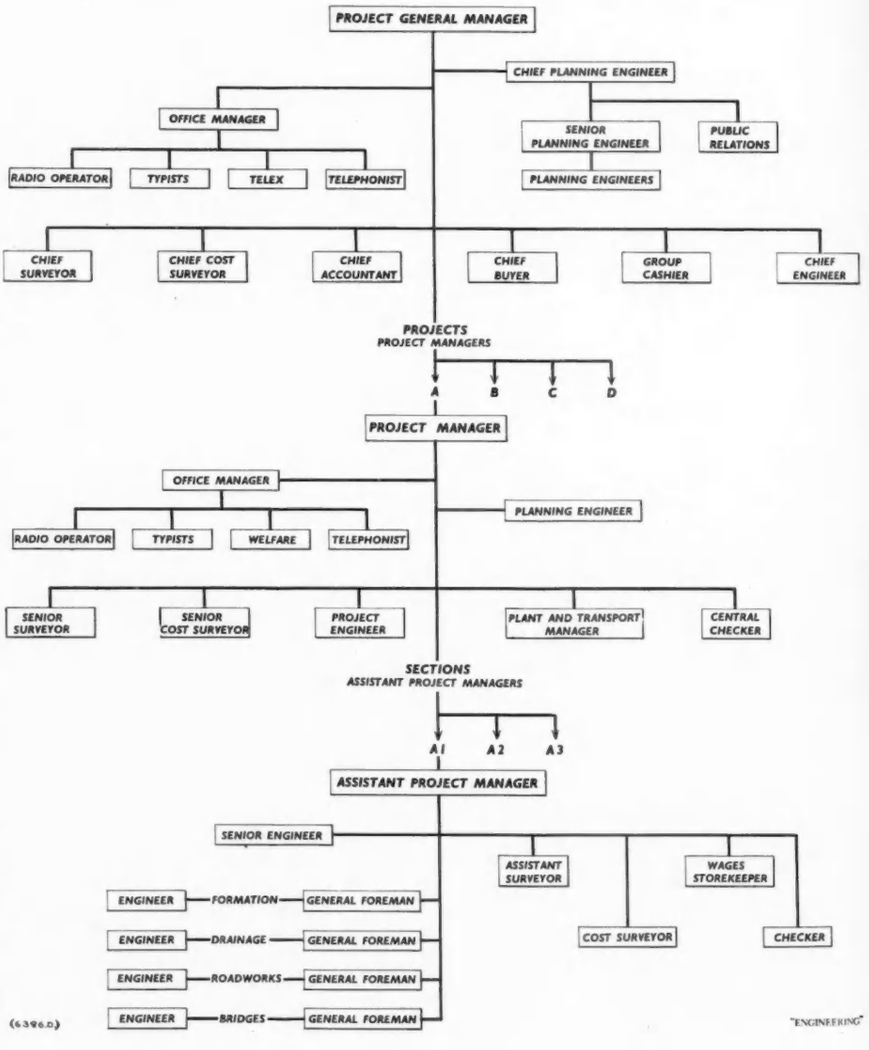
certain sections had no nearby roads and temporary roads have had to be formed. This was particularly the case at the northern end where a high railway embankment cut the line of road and vehicles had to travel seven miles on very narrow lanes to reach a crossing point and return to the motorway. This sort of problem was constantly occurring and our planners had great difficulty in finding solutions.

BRIDGES

There are so many types of bridges in this motorway that it is impossible to deal with each of them in any detail. Nevertheless it must be remembered that with a road of this sort, passing as it does through virgin countryside, land in the ownership or occupancy of various individuals must be severed and access between the two parts of an individual's land must be provided. Provision of this access is additional to constructing means whereby existing roadways that are cut by the line of the motorway can be carried across the stream of fast-moving vehicles. Furthermore, public services such as water mains, gas and electric lines constantly cross the line of the road. These all have to be carried in ducts or over bridges so that they can be maintained after the motorway is in operation. Temporary routes also had to be provided while the new lines were being constructed.

Bridges, therefore, varied from what are known as cattle creeps, which are arch-shaped tunnels under the motorway, or narrow bridges over the motorway, so as to allow a farmer to take his beasts or implements across the line of traffic, up to the large two-level intersections which are necessary to provide access to the motorway itself, as well as somewhat simpler bridges where roads cross over or under the motorway.

In addition, bridges had to be formed over or under railway and canals, and in these cases it



was necessary to maintain the flow of traffic while construction of the new bridge was going on. This in itself has created many problems, but with the cooperation of the Railway and Waterway Authorities these difficulties have been overcome.

Most of the bridges have been designed to a similar pattern. This has allowed us to use the same sort of formwork throughout and has also reduced the number of sizes of steel rods required for reinforcement.

The two-level junctions are major projects in themselves, each costing approximately £250,000. The construction of one of these junctions is shown in Fig. 6, from which the lines of traffic flow to and from the motorway can be followed. It needs to be borne in mind that in each of these main junctions, as well as for many of the minor ones, the new bridges have had to be constructed at points where existing roads cross the motorway and traffic on these roads has had to be maintained throughout the period of our work. This in itself has called for very careful planning so as to ensure that at all times there was a free flow of traffic while we were carrying out the work, and temporary diversions have had to be built. In many cases this has been done by building Bailey bridges which have been removed when the final stage of the construction has been reached.

Those bridges over rivers, of which there are three major examples, have involved a great deal of work in addition to the actual construction of the bridge, because of liability to flooding. In each case numerous flood arches have had to be built. These are of two main types, examples of which can be seen in Figs. 7a and b. At all three rivers the main difficulty has been the poor access from existing roads to these particular bridges, some being as far as two miles from the nearest hard road.

Fig. 6 Two-level road junction with the A50 near Moulsoe.

EXCAVATION

On a motorway such as this where the general gradient is 1 in 50 and with a maximum of 1 in 25, a great deal of excavation has to be undertaken to provide the proper alignment. Our contract involved the excavation of 15,000,000 tons of earth, most of which had to be deposited to form embankments at other points of the road; much had also to be removed from the site altogether and it was necessary to arrange places such as old quarries where this surplus material could be deposited.

The depth of excavation naturally varied tremendously from point to point along the road, the maximum depth being 40 ft in the chalk of the Chilterns close to the Luton/Dunstable road. In a country such as ours there is a surprising variety of subsoil met in a distance of 55 miles, and every conceivable type of soil has had to be dealt with in this particular contract. We have dug hard chalk, dry sand, running sand, very loamy black soil and, in addition, hundreds of thousands of tons of rock which had to be blasted before it could be excavated by even the largest machines.

Wherever possible we have used fast-moving rubber-tyred tractors hauling scrapers, each capable of carrying just over 20 tons of excavated material. These machines can move at speeds of up to 30 m.p.h. and in reasonably dry conditions they can deal with most types of materials. In view of the extremely bad weather which faced us during 1958 it became a problem to keep machines of this sort operating efficiently. However, as a result of careful preparation and by making sure that the tracks on which they had to run were kept level by the use of graders, we were able to excavate over 80 per cent of the bulk material before the digging operations were closed for the winter early in January 1959.

Embankment heights have varied a great deal, the maximum being 45 ft. Compaction of such high banks has been a problem, but by the use of heavy scrapers and bulldozers and sheepsfoot rollers very high consolidation figures have been achieved. The specification called for a dry density including not more than 10 per cent of air voids, and tests have shown results much better than this.

Although digging operations were closed down early in 1959 on account of the weather, work on the various bridges was continued and it says much for the spirit of the men involved on this contract that they were able to carry on with this work in most difficult conditions, when access roads were nearly knee deep in mud, and it was raining and often snowing heavily in addition.

CONCLUSION

Progress made on the main stages of the work by the end of August was:—

	Per cent completed
Bulk excavation	100
Granular base	100
Marginal haunches	100
Lean dry concrete	100
Wearing surface	60
Bridges	100

With the laying of asphalt proceeding at a rate equivalent to three miles of finished motorway a week, and given reasonably good weather, the motorway will be completed within the contract period.

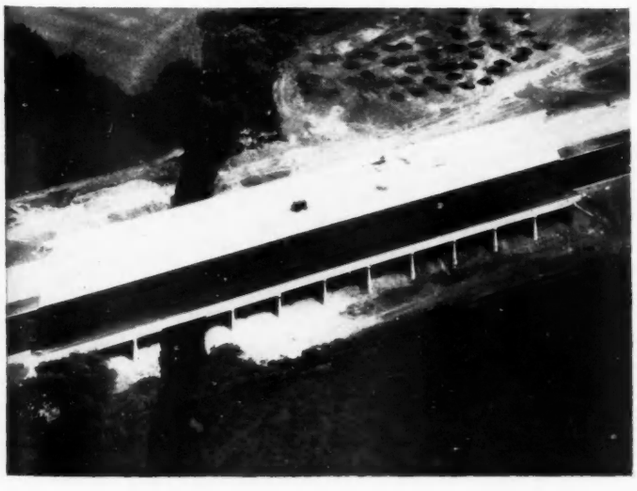


Fig. 7 (a) and (b) Liability to flooding by some rivers has meant the construction of viaducts with flood arches in addition to the main span over the river course. The viaduct over the River Nene is shown on the left and that over the Ouse on the right.

CRITICAL SURVEY OF BRIDGE DESIGN

By O. A. KERENSKY, M.I.C.E.

Freeman, Fox and Partners

The most pressing need in bridge design (Mr. Kerensky) says, is for an accurate assessment of the loading on bridges in the next 100 years. Bridges built now will determine the size of vehicles used in the future. The best design for a bridge may well be obtained by allowing impartial experts to choose from the entries to an open competition. This method is expensive but raises standards.

STRUCTURALLY there are only three types of bridges, the beam, the arch and the suspension. The beam rests vertically on its supports, the arch exerts horizontal thrusts on its abutments, and the suspension cable pulls at its anchorages. Nature provides examples of all three types and man soon learnt to imitate nature so that bridges were almost the first structures he built. Timber beam bridges, masonry and brick arch bridges and primitive suspension bridges have all been built throughout the world's history.

When it is impossible or uneconomic to provide sufficient clearance for a navigable channel, movable bridges are provided. These can be of the swing, bascule, lift, roller, transporter or pontoon types.

Pontoon bridges, developed by the Persians some 2,000 years ago, are the oldest known movable type and are still used today in deep harbours where the expense of providing long spans or very deep foundations is not justified. In these bridges, opening to navigation is achieved by floating away a span or two. The most famous example of this kind of bridge is the 1,500 ft long steel bridge across the Golden Horn at Istanbul, completed in 1939, and the longest is the 6,500 ft long concrete bridge across Lake Washington, Seattle.

EARLY BRIDGES

The prototypes of modern suspension, arch and cantilever bridges were developed in China, India and Mesopotamia, several thousand years B.C. The Romans invented the circular arch and perfected it while producing such masterpieces as the Pont Sant' Angelo in Rome, the Puente Alcantra over the Tagus, the 2,700 ft long Segovia aqueduct in Spain and the famous three-tier Nimes aqueduct in France. With the collapse of the Roman Empire, the art of bridge building was nearly lost to the Western world, but the remnants of knowledge were collected and preserved by religious orders. The famous Pont d'Avignon and the first London Bridge were both built by monks in the 12th century. During the Renaissance important advances were made in both theoretical knowledge and skill of the master builders who gave us such beautiful bridges as the Santa Trinita in Florence (1569), the Rialto in Venice (1591) and the Pont Neuf in Paris (1606).

The primitive bridges were usually built on shallow raft foundations and often meandered across the river from shoal to shoal, sometimes floating on timber rafts. The Romans developed the art of driving timber piles and of constructing watertight cofferdams. The diving bell was invented in the late middle ages. By the end of the 18th century the use of compressed air for sinking foundations was understood, but the first important application of it was made by Cubitt and Wright during the sinking of iron cylinders for the piers of the Rochester bridge in 1851. The first pneumatic caissons were sunk in 1859 for the foundations of the bridge across the Rhine at Khel and the process of sinking underwater foundations with the aid of compressed air became fully established.

Lime mortar has been used in masonry and brick construction from time immemorial. The Romans discovered a natural cement, pozzuolana —a volcanic sand found in Pozzuoli near Naples. When mixed with lime and stone this produced a form of concrete of which they made considerable use, particularly for foundations built under water. Portland cement—the basis of all concrete today—was not invented until 1824.

By about the end of the 17th century Galileo, Hooke, Bernoulli and others had outlined the principles governing the design of beam and frame structures. Bridge building was rapidly developing into a science which, in 1716, received formal recognition by the formation in France of the *Corps des Ingenieurs des Ponts et Chaussées*, and in 1747 became fully established by the founding of the first engineering college in the world—the famous *Ecole des Ponts at Chaussées* in Paris. Its first director, Perronet, further perfected the methods of design and construction of the masonry arch and created one of the most beautiful bridges in France, the Pont de la Concorde, in Paris (1791).

However, the strength of materials in tension was not properly employed until wrought-iron, and later steel, began to be commercially produced and their remarkable and reliable mechanical properties fully appreciated. Between 1820 and 1830 Navier published most of his fundamental work on theory of elasticity and structures.

In 1826 Thomas Telford built the first major iron link suspension bridge of 580 ft span across the Menai Straits. In 1840 Howe patented a truss, in which the diagonals were rigid and the verticals consisted of iron ties, and in 1845 Pratt invented the system in which the diagonals became the iron ties, and the verticals were rigid. Robert Stephenson and William Fairbairns built, in 1850, the first important iron plate girder bridge, the Britannia (tubular) railway bridge, consisting of four continuous girder spans having a largest opening of 460 ft. This bridge was revolutionary in conception and a hundred years ahead of its time. Major developments followed: in 1851 Warren built his first Warren truss bridge—the Newark bridge over the river Trent; in 1866 Gerber of Germany designed the first major cantilever bridge (426 ft span); Eads completed the building of the first modern steel arch bridge in 1870, the St. Louis bridge over the Mississippi with three spans of over 500 ft each; and in 1882 Benjamin Baker began building the great Forth railway bridge in which he used tubular compression members and high tensile steel. He, too, was well ahead of his time.

The real development of the suspension bridge came with the invention by John Roebling of the steel wire and of the parallel wire cable (1841). His famous Brooklyn bridge of 1,596 ft span across the East river (1870-1883) is the prototype of all modern suspension bridges. The method invented by Roebling of erecting the cables by spinning of the wires is still used today and will be adopted on the new Forth road bridge. For spans over about 1,500 ft suspension bridges should be economic and for spans over about 2,000 ft they reign supreme. The longest span so far built is the 4,200 ft span of the Golden Gate bridge (1937). A double deck bridge across the Narrows in New York, with a span of 4,260 ft, has just been begun and a 4,500 ft span bridge across the Humber has been designed. A hundred years ago Roebling predicted that spans of 6,000 ft would be built and these are now practicable.

The pioneer engineers, obliged to arrive at solutions of their problems from first principles unhampered by standardised methods of design, fabrication and erection, often produced bold and theoretically efficient structures which stood the test of time. Probably, however, they just as often built better than they knew. The fact that today we are still able to use many of the bridges designed for light railways, or horses and carts, is much more due to the extremely conservative assumptions made by the designers than to their prophetic foresight of the future requirements.

MODERN STEEL BRIDGES

The introduction of rolled steel sections and of mass production methods in the fabricating shops during the second half of the 19th century almost eliminated smithed and curved work so that, in general, steel designs became controlled by the availability of cheap sections and the limitations of the standardised methods of fabrication and erection.

A very large number of railway and highway steel bridges were built in the 60 years between 1870 and 1930. Naturally the various developments in the theory and methods of analysis enabled the designers to increase the efficiency of structures, while the improved machinery and mass-production methods of fabrication lowered their costs, but on the whole there was little real advance during that period in the qualities of materials, techniques of construction, and methods of design.

There is no doubt, however, that the introduction of electric welding and machine gas cutting has made more efficient forms of construction in steel again economically possible, the scope for new development almost unlimited, and some of the conventional methods of analysis obsolete.

Since the war a deck used in ships and known as " battle deck " has been adapted to bridges. It consists of a steel plate reinforced on the underside by welded ribs (flats, sections or troughs) and is essentially a welded form of construction. Its adoption is economic for all long-span bridges, particularly when the plate and stiffeners are also utilised as flanges of the main girders, resulting in a box or a U-shaped structure. Instead of a steel plate, a reinforced concrete slab anchored to the steel girders and acting compositely with them has been found to be economic in many post-war bridges of medium spans. Both the steel and the concrete decks, when used as main elements of the structure, must be carefully waterproofed and protected by a wearing surface to eliminate any reduction of strength from corrosion or wear.

The design of the orthotropic plate and of the composite steel and concrete decks is somewhat complex and calls for a review of the present methods of " elastic " design. Adoption of the ultimate strength criteria would lead to further economy.

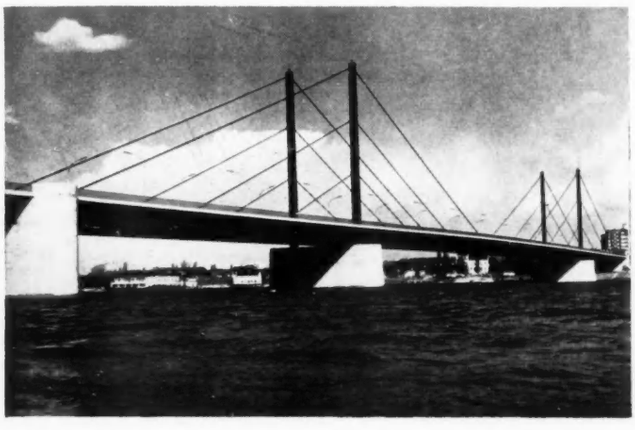
Plate girder bridges, because of their attractive appearance are particularly popular in localities where aesthetic considerations are of importance. Considerable advances have recently been made in the design of plate girders, but further research into the behaviour of thin webs is still needed.

After the destruction during the war of thousands of bridges in Germany and France, their engineers had an exceptional opportunity in bridge building, and they have not wasted it. Perhaps the most interesting French bridges are the Neuilly bridge in Paris, which, although completed in 1939, pioneered post-war develop-

Paper entitled " Bridges—A Survey " read before the Engineering Section of the British Association at York, September, 1959 (See note at head of page 175).

ment of all-welded construction in high tensile steel; the 328 ft span Corneille bridge in Rouen (1952)—one of the first bridges in which high tensile steel plate girders acted in combination with a reinforced concrete deck slab. There is also the Tancarville suspension bridge near Le Havre, only completed in July, 1959, with a central span of 2,000 ft, the largest so far built in Europe. Of its many new features the most interesting are the 390 ft high towers constructed in reinforced concrete, the main cables made up from wire ropes and the composite construction of the suspended structure. Each 3,500 ft long rope, weighing approximately 27 tons, was erected by being pulled across the opening while supported by monowheels from a temporary ropeway. The composite steel and reinforced concrete deck also acts as the top chord of the stiffening trusses. These are continuous at the towers and fastened to the centre of the cables, thus developing considerable additional stiffness.

To Germany must be given full credit for developing the box-girder bridges, first conceived by Stephenson a hundred years ago. One of the first of the modern kind was the Düsseldorf Neuss bridge completed in 1952. It has a central span of 676 ft. The structure consists of two box girders joined together by cross girders and bracing, the asphalted steel deck acting as top flange of the girders. The Düsseldorf Nordbrucke bridge (1957) has a central span of 858 ft,



Düsseldorf Nordbrucke: A cable-stayed steel-box girder bridge, that was built in 1957.

and the bridge in Cologne, now in the course of erection, will have a central span of 990 ft. In both these structures the box-type main girders are continuous over the river piers and carry a steel battle deck. They are additionally supported at points between the piers by inclined guys which pass over masts at the piers and are anchored to the side spans. This device of partial suspension appreciably extends the economic range of the slender plate girder form of construction and undoubtedly will also be applied to concrete bridges.

The 40 ft wide bridge across the river Sava in Yugoslavia, designed by M.A.N. of Germany is perhaps the most striking example of the modern plate girder type. It has a central unsupported span of over 850 ft and consists of an all-steel inverted U-shaped girder designed by a semi-empirical ultimate strength method. The bottom flanges are of riveted construction.

GRIP BOLTS

In recent years, field joints in main trusses and plate girders and in various deck connections have frequently been made with tensioned high tensile steel bolts in preference to riveting or welding. These bolts act as grips, the shear in the joint being resisted by friction between the clamped surfaces and for maximum economy the bolts should be made of very high quality steel. Over 200,000 tensioned bolts were used in the 3,400 ft long Auckland Harbour Bridge, opened to traffic in May, 1959. All the joints in the stiffening trusses of the second longest suspension bridge in the world—the Mackinac bridge of 3,800 ft span and 8,614 ft overall length, completed in 1957—were made with grip bolts. Perhaps an even more striking example is the use of these bolts in all the joints of the 3,350 ft long Carquinez bridge near San Francisco (completed in 1958). In this bridge all the members of main trusses were shop welded in high tensile steel, of which about 3,000 tons was "T1" steel with a yield of 40 tons per sq. in and a basic working stress of 20 tons per sq. in. A more efficient application of such bolts is to use them as pretensioned ties placed parallel to the direction of stress in a member, as in Volta bridge (1957).

REINFORCED AND PRESTRESSED CONCRETE

Most of the credit for the early development of reinforced concrete must be given to Monier (1823-1906) and Hennebique (1843-1924).

The first reinforced concrete bridge (52 ft span) was experimentally built in 1875 and in 1898 Hennebique designed and built the first notable reinforced-concrete arch with a span of 172 ft. The combination of concrete and steel in a mouldable form has given engineers great scope for exercising their ingenuity in developing new forms of structures.

Striking monolithic bridges in which the decks are no longer loads supported by girders but are integral parts of the whole structure were produced during the 20th century by Considere, Maillart, Freyssinet and others. The largest single-span concrete bridge so far built is the Sando bridge in Sweden (1943), while Waterloo bridge is perhaps the best example of a reinforced-concrete bridge in Great Britain, and the Caracas Arch bridge of 500 ft span designed by Freyssinet (1952) one of the most remarkable in the world.

In 1904 Freyssinet conceived the idea of improving the resistance of concrete elements to tensile forces by prestressing, i.e. inducing compressive stresses in the concrete by tensioning high tensile steel wires, rods or cables, embedded or contained in that element. Undoubtedly this is one of the most important developments in bridge construction since the invention of the reinforced concrete itself. Its full significance was not generally realised until a few years ago and Freyssinet himself did not devote his undivided attention to its development until 1929.

Prestressing demands concretes of high quality and strength, and a renewed interest in concrete technology resulted in rapid advances in this field to give concretes with crushing strengths of 8,000 or even 10,000 lb per sq. in.

Prestressing not only greatly increases the economic range of concrete bridges, but also encourages the construction of monolithic concrete structures from assemblies of precast elements. For short-span bridges precast prestressed beams with concrete topping cast *in situ* are an attractive alternative to reinforced-concrete slabs cast *in situ*. For medium and large spans, post-tensioning of precast or progressively cast *in situ* elements of the bridge offers an almost unlimited opportunity to the designer. Worms bridge in Germany (1953) and the Clifton bridge in Nottingham, England (1958), are fine examples of this type of construction.

Prestressing also provides a facility for altering reactions on the supports by the linear transformation of the cable profile. This has been utilised by Professor Vanderpitte of Belgium to produce a type of suspension bridge in which the concrete stiffening beam also acts as a self-anchoring device and is prestressed thereby. Another new form of construction has been proposed by Ricardo Morandi for the Maracaibo bridge in Venezuela with a central span of 1,300 ft and side spans of 551 ft.

In this proposal the superstructure consists of two cantilever beams which are supported at one end by the piers and at points 443 ft from the pier by inclined cables. A suspended span of 152 ft fills the gap between these beams. The cable ties pass over 210 ft high pin-ended portal extensions of the main piers and are attached to the "anchor" beams at points 426 ft from the piers. The ties are tensioned until maximum possible dead load stresses are developed in them. The horizontal components of the pull in the ties prestress the cantilever and anchor beams.

River Sava bridge, Yugoslavia. A riveted steel plate girder of 950 ft span.

MATERIALS

Modern materials suitable for bridgework are stone, brick, timber, steel, concrete and light alloys. The first two of these are seldom used now, though their excellence has been proved by the surviving Roman and Medieval bridges. Stone in particular is one of the most durable materials and only the very high cost of construction prevents its wider use today. After the war French engineers have revived the art of masonry construction and have built many such arch bridges of small and medium spans. Timber is still used for small bridges in timber growing countries and the very recent developments with glued laminations, mechanical connectors and adhesives may make this excellent material again attractive.

Concrete can be regarded as artificial stone mouldable to any shape. The relative merits of concrete and steel for small and medium-size bridges are still unresolved and for spans up to about 500 ft the two materials are highly competitive. For larger spans steel is the economic material, but ordinary mild steel is gradually giving way to the low-alloy steels of higher strength. Further substantial economy of steel, combined with an increased range of application, will be achieved when high tensile weldable

steels, having a yield of 30 tons per sq. in or more, become commercially available at reasonable prices. Such steels have been produced and used in some of the great bridges built since the war in Germany and the United States. Parts of the Düsseldorf Neuss bridge were made from steel with a yield of 33 tons per sq. in and, as already mentioned, in the main trusses of the Carquinez bridge T1 steel with a yield of 40 tons per sq. in was used. Special high quality steels are also available in Great Britain, but have not so far been used in bridgework.

Light alloys probably will play their part in the future, but at present their cost makes their use uneconomic except in special circumstances, such as for military bridges, some movable bridges and for increasing the carrying capacity of old bridges.

MAINTENANCE

With the ever increasing cost of labour, considerable attention has been paid in recent years to the problem of reducing maintenance on all structures.

In the early enthusiastic days of concrete development it was commonly assumed that this material would be as durable as good masonry, requiring practically no maintenance. Unfortunately the importance of the correct mix and of careful placing and curing was not properly appreciated by some engineers, and many reinforced concrete structures have developed serious defects after a comparatively short time in service.

The invention of prestressing has brought in its wake rapid improvements in the quality of concrete generally. Strict control of materials, proportions, mixing and placing is today invariably applied in all important work. Prestressing has a further advantage in that it can altogether eliminate cracking of concrete under load and thus remove one of the main causes of deterioration.

In steel construction much more care is exercised in the development of details. All crevices, pockets and slots are avoided. Tubular or box members sealed at each end are used whenever practicable and elaborate protective treatments are applied to all exposed surfaces in the first instance. It has been fully established that for the best results protective coatings of paint or metal must be applied on a perfectly clean dry surface, free of all mill scale and foreign matter. The popular pre-war practice of weathering and wire brushing the steelwork prior to painting has been replaced by the much more expensive process of grit or sand blasting, or pickling in acid, or flame cleaning. Many new protective coatings have been developed and of these metallisation by spraying zinc, aluminium, or a mixture of the two, is perhaps one of the most promising. The metal coating should be regarded as a priming coat, requiring thorough protection by painting. No part of any bridge should be inaccessible for maintenance unless it is certain that none will be required during its life. When services such as gas, water or electricity are carried, or likely to be carried in the future, proper ducts with adequate access and drainage should be provided. Surface water should never be allowed to splash on any part of the bridge structure.

BRITTLE FRACTURE AND FATIGUE

It has already been stated that the introduction of welding enables the designer to produce monolithic structures in steel with considerable economy in weight, improvement in appearance and saving in maintenance costs. Unfortunately welding also emphasises two weaknesses of steel —its liability to brittle fracture at low temperatures and to fatigue cracks when subjected to a large number of stress cycles.

These two characteristics were always there, of course, but welding raises the critical temperature at which brittle fracture is liable to occur, produces stress raisers which help to initiate fractures and, worst of all, results in structures liable to catastrophic failures. In riveted construction sudden failures due to either of these causes were very rare because both the brittle and the fatigue cracks were usually arrested by the rivet holes.

Fatigue, that is, the lowering of the ultimate strength of the material when subjected to repeated stress cycles, is a very complex phenomenon but in the main it is related to the following four factors:—(1) nature of stress cycle; (2) number of stress cycles; (3) details of construction; and (4) quality of steel.

In his design of the Forth bridge Benjamin Baker attempted to make allowances for the effects of fatigue by adopting low working stresses. In subsequent years this caution has been somewhat forgotten. The testing of welds and the much publicised failures of aircraft have made structural engineers again fully conscious of the danger. Much research work has been, and is being, carried out in Europe and the USA in an attempt to give the designer more reliable guidance.

At present, at least three British committees are dealing with the problem of fatigue in structures. In the past most of the efforts were directed to establishing safe working stresses for various steels using different types of connections and methods of fabrication, related to the number of critical stress cycles. Unfortunately statistical data on the number and nature of stress cycles to which the various railway and highway bridges have been actually subjected during the last 70 years has not been collected and analysed, and perhaps even less has been done regarding the assessment of the number of cycles due to different classes of loadings to which the old and the new bridges will be subjected during the next 100 years.

Fatigue is of the greatest importance in railway bridges and in Great Britain the railway authorities are now in the process of collecting this data. A proper appreciation of all the factors affecting fatigue is essential if the safe life of the old bridges is to be dete mined, and if in the design of the new ones, safety is to be combined with economy.

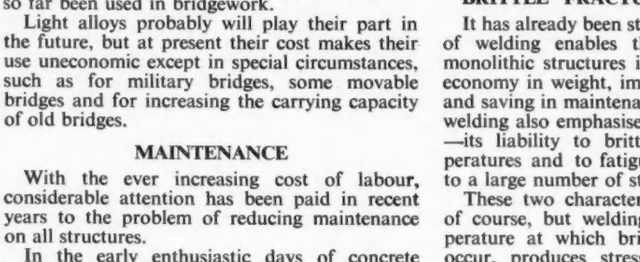
Steels are now required to possess three qualities—weldability, notch ductility, and resistance to fatigue—in addition to strength. The metallurgists and the steel makers are engaged in the development of such steels for structural purposes at commercially competitive prices. In Great Britain a British Standard Specification was published in 1958 covering four grades of notch ductile steels but unfortunately all of these are of the mild steel quality, although special high tensile weldable and notch ductile steels are available.

LOADING DEMANDS

The only purpose of a bridge is to carry traffic and services across the space to be spanned. The types of traffic to be carried, that is, railway highway or pedestrian, is usually known but their total effects on the bridge, now and in the future, are very difficult to assess. Railway locomotives and wagons have continually increased in weight, while their operational qualities have steadily improved. The introduction of electric and diesel power and of new techniques in track laying will result in further improvements. It is possible that the continual growth in the weight of railway traffic has been arrested, but research is needed to ascertain the dynamic effects (impact, sway, etc.) of the new locomotives and rolling stock.

The problem of highway loading is, perhaps, even more complex. Somehow engineers have to assess the future trends in vehicle design and at the same time to decide on the probable and possible maximum intensity of traffic on any given length and width of bridge. The development of atomic power and the recent trial flights of the Saunders-Roe hovercraft do not make their task any easier.

Individual loads of 200 tons and over are now carried on British highways and new bridges must be designed for them. These heavy concentrated loads usually control the sizes of all deck elements and occasionally of main girders. Fortunately design and movements of the special vehicles are to some extent controllable by the responsible authorities. On the other hand, the number, weight and spacing of the ordinary heavy lorries, buses and cars, that are likely to use any particular bridge at any given moment can only be guessed. For example, it is perhaps just possible to envisage a 100 ft span two-lane bridge completely covered by 30 ton lorries nose to tail together with a crowd of cyclists and pedestrians on the adjacent cycle



Auckland Harbour Bridge, opened last May. Erection of the 600 ft navigation span after floating out.

Caracas Bridge—Venezuela. A reinforced-concrete and prestressed concrete arch of 500 ft span. Designed by Eugene Freyssinet.

tracks and footways, but this would be an absurd assumption for a span of 500 ft or even 200 ft with dual three-lane carriageways. Obviously the intensity of loading must reduce with the length and width of the bridge, but the rate of reduction assumed can only be a matter of opinion, even if backed by statistical data and the theory of probability. Nevertheless, much more can be done in this field, both as regards the assessment of the intensity of traffic for which the bridges must be designed, and the factors of safety which should be provided.

LOAD FACTORS

In Great Britain, loadings used in the design of new railway and highway bridges undoubtedly represent the very exceptional rather than the normal conditions, and perhaps should be treated as such.

It has been said that unless there are occasional failures of bridges (as indeed there were in the pioneer days) it is obvious that the designers are erring on the side of safety. But who would wish and has the right to associate himself with a calculated risk of failure? Nevertheless, it is the duty of the engineers to strive for maximum overall economy. It could perhaps be argued that bridges should be designed just to stand up when subjected to most exceptional combinations of loadings, and that it may even be advisable to design some bridges for a specified span of life, as is often done in other fields.

During the next decade millions of pounds sterling will be invested in the new railway and highway bridges designed by the most up-to-date methods, at high working stresses, to carry the realistically, if pessimistically, assessed loadings. In future the design of locomotives and of the heavier types of road vehicles should be, and undoubtedly will be, controlled by the carrying capacity of these bridges.

In addition to the traffic, bridges have also to withstand the forces of nature: temperature changes, snow, currents, earthquakes and winds. Of these only the last two are difficult to assess. It is generally taken for granted that it is not economic, if not impossible, to design bridges to withstand earthquakes of maximum intensity, but moderate earthquakes can be catered for on a semi-empirical basis.

In recent years much research has been done on the effects of wind on different types of Structures. Many simplified rules for ascertaining the static wind effects exist, and the latest British Standard can be taken to be reliable for bridges of moderate sizes. But for a structure in which wind forces are really important—long-span bridges—wind tunnel tests are advisable. It is also debatable whether the effects from winds of hurricane strength should be combined with those from live loads of maximum intensity or whether it would be more reasonable to ignore such an improbable occurrence. The latest British and American specifications for highway bridges assume that maximum live loads can coexist only with ordinary strong winds, whereas most specifications for railway bridges take the more pessimistic view.

AERODYNAMIC INSTABILITY

Although the static effects of wind have been known for a long time, certainly since the Tay bridge disaster in 1879, the aerodynamic effects were not properly understood until a few years ago. Individual elements of any structure and excessively flexible bridges that are of certain shapes and proportions are liable to cyclic vibrations or oscillations when subjected to repeated rhythmic loadings (e.g. marching soldiers) or winds. If allowed to continue such oscillations may result in failure of an element or of the whole structure.

Suspension bridges which are inevitably much less rigid than bridges of other types are particularly susceptible to this danger, and many fine suspension bridges have suffered from and have even been destroyed by violent oscillations caused by strong and sometimes only moderate winds. The most notorious case was the failure of the Tacoma bridge in 1941, a few months after it was completed. Since then much experimental work has been done in the United States and in this country on the aerodynamic instability of bridges. Modern theories explaining this phenomena take into account, separately or in combination, the effects of forces due to formation and shedding of eddies or vortices, the variation of angle of attack of the wind on the oscillating structure and the effects of flutter.

When air flows past a structure eddies are formed behind it. At low speed these eddies remain trapped, but at high speeds they are carried away as it were by the stream and this causes sudden redistribution of the aerodynamic pressure on the structure, which, in certain circumstances, may set up oscillations. Many investigators consider the eddies to be the primary cause of aerodynamic instability. On the other hand, Steinman attaches major importance to the variation of angle of attack of wind on the deck and suggests that the aerodynamic behaviour of a structure can be predicted from static model tests. Flutter effects are essentially concerned with coupled oscillations, that is, a combination of vertical and torsional movements, as in the case of an aerofoil (for which no simple independent oscillations are possible). For a bridge structure, however, particularly one with top and bottom lateral systems, the torsional and vertical frequencies may be appreciably different, which greatly reduces their liability to coupled oscillations and makes the application of the flutter theory of doubtful value.

In their final report in 1952 on the aerodynamic work for the Severn bridge, Frazer and Scrutton conclude that the theoretical prediction of the behaviour of any section in wind is extremely difficult and unreliable, and that with the present state of knowledge experimental and semi-empirical methods must be used for determining the stability characteristics of a proposed structure. The same opinion is expressed by George S. Vincent in his paper to the American Society of Civil Engineers (October, 1958). However, certain general requirements, which should at least ensure that the preliminary designs are made on the right lines, are now well established. These include:

(1) The use whenever possible of open sections allowing free passage of wind.

(2) A reduction of the vertical aerodynamic pressure to a minimum by the introduction of openings in the deck plane, a gap between the leading edge of the section and the main deck being particularly beneficial.

Further improvements should result from the provision of (1) stiff stiffening girders, (2) top and bottom laterals, (3) cable stays, and (4) artificial damping devices.

It has also been established that the aerodynamic behaviour of a suspension bridge can be reliably predicted from tests with simple sectional models, that is, short rigid models of a sample length of a suspended structure mounted with freedom to oscillate, and that elaborate full models simulating the physical properties of the whole structure are not necessary.

STANDARDISATION

In Great Britain a vast programme of provision of new highways and of modernisation of railways calls for an intensive study of the economics of bridge construction. The six railway regions are attempting to produce standardised designs at least on a regional basis, and it has been suggested that the Ministry of Transport or other competent body should produce a number of standard railway and highway bridges. While it is true that certain sets of conditions occur repeatedly and standard solutions could be adopted for these, it is doubtful whether in the long run such a procedure would be in the interests of the engineering industry and of the country as a whole.

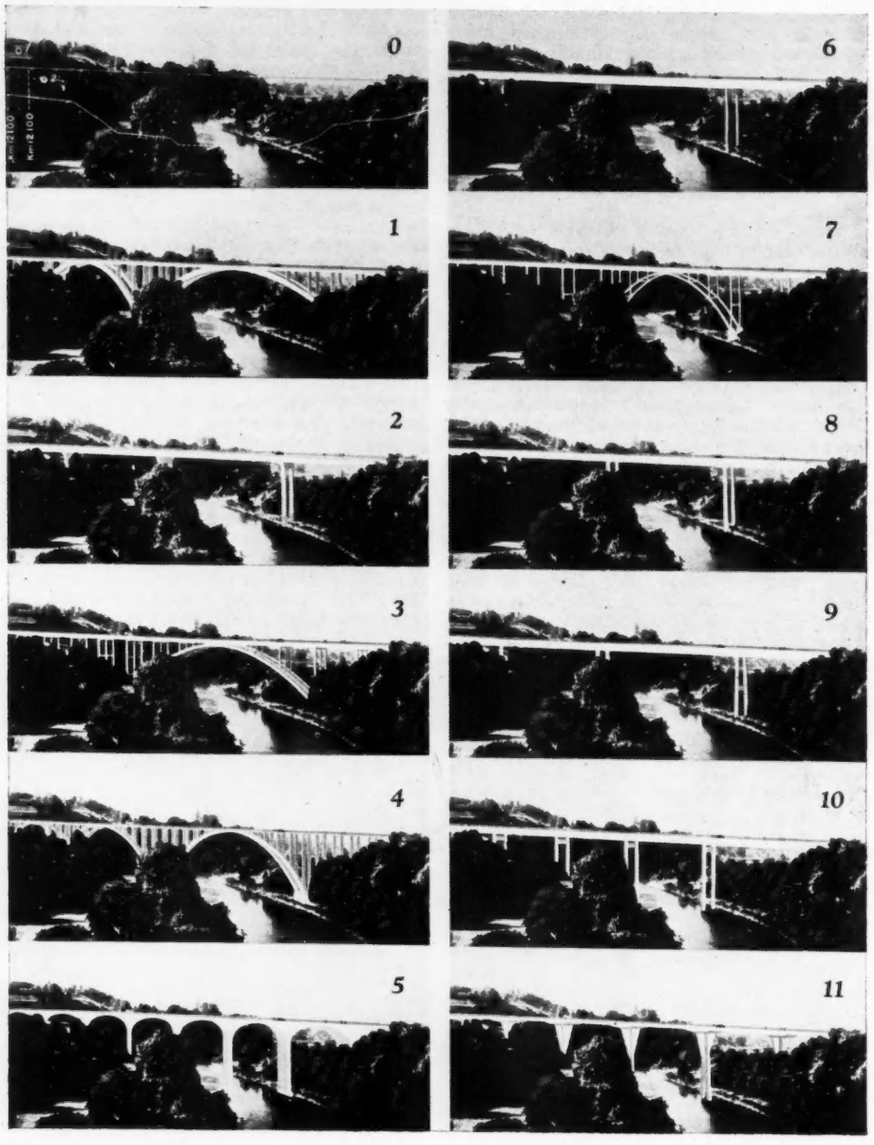
The present system of employing many minds on the solutions of similar problems results in the adoption of many different types of bridges, use of different materials, and freedom to exercise ingenuity during construction. Undoubtedly this enhances the art of bridge building, at the same time giving the travelling public a variety of structures to admire and criticise. Nevertheless, even if it is inadvisable to standardise all bridges, it is certainly advisable to adopt standardised types for long sections of new highways and railways, thus achieving substantial economies in the design and construction as well as giving individual character to each section.

With modern plant and site organisation, first class highways can be built at great speed, and it is essential that bridges should be planned and designed with this in mind. The cost of a bridge depends on four M's: Materials, Men, Machines, and Money, that is, on the quantity and quality of materials, the amount of manpower and plant involved in fabrication and erection, and the cost of providing capital during the construction and for the subsequent maintenance of the structure. Thus a lighter prestressed concrete beam may be more expensive than a heavier reinforced concrete one and a structure that is cheapest in the first instance may easily prove to be the more expensive in the long run. It is possible that the current fashion of producing structures involving the very minimum amount of material, which has its roots in the war and post-war austerity years, is out of date, the most precious element now being manpower. This is particularly true when dealing with a structure in which its own weight is of little consequence.

Motorway flyover junction of reinforced and prestressed concrete at Fort Worth, Texas, USA.

In the design of modern highways much attention is paid to the comfort of the travelling public. The bridges must fit into the complicated layouts of flyovers and junctions, and the days of "kinking" a road in order to simplify the structure have gone. Slender, curved, and skew bridges continuous over several supports are being built in ever increasing numbers and further improvements in the methods of design of these types of structures are urgently required.

Model stress analysis and the use of electronic computers can give quick and relatively cheap solutions to complex indeterminate structures, and open new fields in the search for the most economic designs. Generally it is economic and proper to devote a considerable amount of time to the design of all but the very simplest



Weinland Brücke—Switzerland. Some of the 21 competitive designs entered.

0. *General view of the site.*
1. *Three-hinged reinforced concrete arch.*
2. *Prestressed concrete continuous beams.*
3. *Reinforced concrete two-hinged arch. (This took 2nd prize.)*
4. *Reinforced concrete and prestressed arches.*
5. *Reinforced concrete viaducts.*
6. *Prestressed concrete continuous beams. (This took 1st prize.)*
7. *Reinforced concrete arch.*
8. *Prestressed concrete continuous beams.*
9. *Prestressed concrete continuous beams.* (*Cheapest design.*)
10. *Continuous steel beams with reinforced concrete deck.*
11. *Prestressed concrete structure.*

of structures as money spent on the selection of the best layout and form of structure, and on the development of neat and efficient details, is usually more than repaid by the saving in cost of the finished product. Unfortunately there is no easy yardstick with which to measure the efficiency and quality of a design because truly comparative figures for alternative designs are hardly ever readily available.

COMPETITIVE DESIGNS

To overcome this difficulty some authorities, particularly abroad, call for tenders based on competitive designs. Sydney Harbour bridge is perhaps the classical example of this method. Six firms (American, Australian, Canadian, English and Scottish) submitted twenty tenders offering arch, cantilever and suspension bridges for this £5 million project.

Another instructive example is to be found in the competitive tenders and subsequent construction of the 1,000 ft long Weinland bridge in Switzerland to carry a new highway across the river Thur. Although in this case the competition was limited to firms practising in Switzerland, 21 competing proposals were submitted of which 12 were in prestressed concrete, 5 in reinforced concrete and 4 in steel, and a selection of 11 of these is shown in the accompanying plate. The selected design was a prestressed concrete 4-span continuous beam bridge on slender columns. A very similar design in steel was estimated to cost about 8 per cent more and a reinforced concrete arch design which was awarded the second prize was some 9 per cent cheaper. Although after long and arduous efforts the most attractive design may have been selected by the judges, it was by no means the cheapest, its final cost being nearly 50 per cent above the lowest tender, thus clearly illustrating the inherent weakness of this method.

This procedure has also been recently adopted for several large bridges in Germany, India, Pakistan, Iraq and other countries. For the design of the latest bridge across the Rhine in Cologne, 39 tenders were submitted. Although much thought has been given, by all concerned, to the problem of obtaining the most efficient design for any particular crossing at the lowest cost, no universal satisfactory solution has so far been found.

AESTHETIC ASPECT

Public authorities and the engineers are today very much aware of the fact that economy is not the only criteria by which a design should be judged. They realise that most bridges should be works of art rather than mere utilitarian devices, that they should blend with the surrounding country and be so proportioned as not to offend the eye of an expert and, if possible, give pleasure to laymen.

The designer usually has to comply with certain requirements regarding traffic, gradients and navigation clearances, but has a wide choice of the layout and type of structure. There is seldom, if ever, a unique solution to any bridge problem, and in the end the engineer has to rely on his own judgment and personal preference.

BIBLIOGRAPHY

Abeles, P. W., " The Competition for the Design of the Weinland Bridge, Switzerland." *Civil Engineering*, vol. 53, March 1958.

Anonymous, " Visits aux Chantiers du Pont Soudé de Neuilly sur Seine." *Bulletin d la Société des Ingénieurs Soudeurs*, vol. 9, Aug.-Nov. 1938.

Anonymous, " Le Pont Route de Tancarville," *Travaux*, April 1959.

Baker, Benjamin, " The Forth Bridge," paper read at the British Association, Southampton 1882. ENGRG., vol. 34, 1882, p. 217.

Beyer, E. and Tussing, F., " Die Neue Rheinbrücke Düsseldorf-Neuss." *V.D.I. Zeit.*, vol. 94, January 1952.

Bill, Max, *Robert Maillart*, Architektur A.G. Edition, Erlenbach-Zürich.

Booth, L. G., " Timber Construction in Bridges." 50th Anniversary Conference, Institution of Structural Engineers, October 1958.

Bowie, P. G., and Rowe, R. E., " Developments in the Design and Construction of Concrete Bridges." 50th Anniversary Conference, Institution of Structural Engineers, October 1958.

Bradfield, J. J. C., " The Sydney Harbour Bridge and Approaches ". *Proc. Inst. C.E.*, vol. 23, 1934.

Finch, R. M., and Goldstein, A, " Clifton Bridge, Nottingham: initial design studies and model test," and " Clifton Bridge, Nottingham: design and construction." *Proc. Inst. C.E.*, vol. 12, March 1959.

Freyssinet, E., " The Birth of Prestressing." *Travaux*, June 1954.

Godfrey, G. B., " Post-War Developments in German Steel Bridges and Structures." *The Structural Engineer*, February 1957.

Guyon, Yves, " Long-span Prestressed Concrete Bridges Constructed by the Freyssinet System." *Proc. Inst. C.E.*, May 1957.

Hamilton, S. B., " The Historical Development of Structural Theory." *Proc. Inst. C.E.*, Part III, vol. 1, December 1952.

Henderson, W., " British Highway Bridge Loading." *Proc. Inst. C.E.*, Part II, vol. 3, June 1954.

Hollister, L. C., " Carquinez Toll Bridge Project." *Civil Engineering (USA)*, February 1957.

Kerensky, O. A., The Maitland Lecture 1959: " Long Span Suspension Bridges." *The Structural Engineer*, July 1959.

Kerensky, O. A., " Recent Developments and Trends in British Steel Bridges." 50th Anniversary Conference, Institution of Structural Engineers, October, 1958.

Marshall, W. E., " The Future of Aluminium Bridges." 50th Anniversary Conference, the Institution of Structural Engineers, October 1958.

Schaechterle, K., and Wintergerst, L. " Wiederaufbau der Rheinbrücke Düsseldorf-Neuss." *Bauinggenieur*, vol.27. N.1., January 1952.

Schüssler, Karl, and Braun, Franz, " Wettbewerb 1954 zum Bau einer Rheinbrücke oder eines Tunnels in Köln in Zuge Klappergasse-Gotenring." *Der Stahlbau*, November 1957.

Smith, Shirley H., *The World's Great Bridges*. Phoenix House, London 1953.

Steinman, D. B., *Bridges and their Builders*. Harcourt, Brace, New York.

Various Authors, Jubilee Symposium on High Strength Bolts, the Institution of Structural Engineers, June 1959.

Velitchkovitch, M., " Les Travaux de Reconstruction du Pont Corneille." *Travaux*, April 1952.

Wolchuk, Roman. " Orthotropic Plate Design for Steel Bridges " (Save Bridge). *Civil Engineering*, USA, February 1959.

British Association Meeting

ROAD IMPROVEMENTS: CHOOSING PRIORITIES BY A NEW FORMULA

By DR. G. CHARLESWORTH, D. J. REYNOLDS, B.Sc.(Econ.), and J. G. WARDROP, B.A., Road Research Laboratory, DSIR

An estimate of the economic benefits to be expected from road works showed that for eighteen schemes, four gave returns on capital outlay of under 5 per cent and five gave returns of over 15 per cent. Allowances are made for personal accidents and the costs of congestion. The rate of return on the cost of work should be used to decide priorities between different road projects. Observations reported show how much traffic rural roads must carry before it is economically justifiable to widen them.

HISTORICALLY, the extent to which economic development has taken place in most countries has depended on such factors as technological progress and availability of resources, but such development has not usually taken place without substantial improvement in means of transport. Indeed, industrial and economic progress normally depends on the provision of good transport to make materials and markets more accessible and labour more mobile. In addition, the higher standards resulting from that progress have led to a substantial and increasing demand for private passenger travel for recreation, social life and personal convenience.

In view of the large part played by transport in an advanced economy it is important that consideration be given to ways of reducing its real cost, including the cost of the track or road.

In Great Britain road transport is assuming an ever increasing importance. Vehicle registrations have increased from about 4 million in 1950 to about 7½ million in 1958, of which 4½ million were private cars, 1½ million motorcycles and 1½ million goods vehicles. It is estimated that in 1958 road users spent a total of about £3,000 million, including taxation, on road vehicles and their use, of which about £500 million represented net investment in new vehicles. Of the remainder, about 40 per cent was spent on private transport by car and motorcycle and another 40 per cent on goods transport. The total spent on rail transport was about £500 million in 1958.[1]

Expenditure on road transport is of direct importance not only to the individual and to industry, but also to the Government. Of the above total of £3,000 million, some £370 million represented tax on fuel and licence duties and about £130 million was tax on new vehicles.[2] Total expenditure on roads, which is not included in the total of £3,000 million, was about £130 million in 1957-58 of which £27 million was for new works[3, 4]; present intentions are for expenditure by the Government on new works to rise to about £60 million per annum.[5]

Of perhaps even more consequence are the trends in expenditure and traffic on the roads. In 1950 expenditure of real resources (i.e. expenditure net of tax) on roads and road transport was about 10 per cent of the net national income,[6] whereas in 1958 it was estimated to account for some 14 per cent. Making allowance for changes in prices it is estimated that expenditure in real terms on roads and road transport increased by 60 per cent between 1950 and 1958. In this same period the estimated total annual mileage by motor vehicles increased by about 75 per cent, private cars providing the largest element in growth. If this increase is assumed to continue at the same compound rate, it will lead to a doubling of traffic in ten years. The rapid increase in congestion is known to be already adding significantly to the costs of travel by road, and without remedial action the situation is bound to worsen.

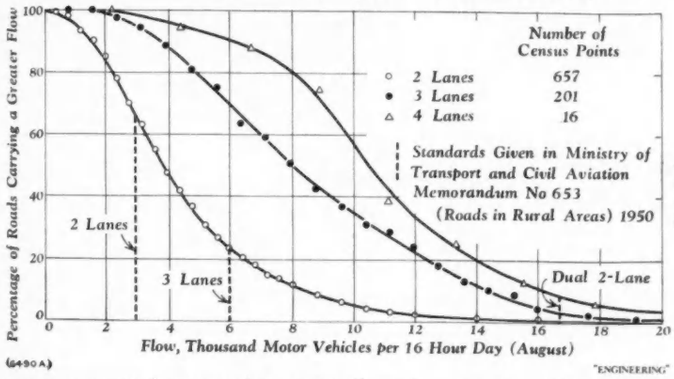

Percentage of Roads Carrying a Greater Flow
Number of Census Points
2 Lanes 657
3 Lanes 201
4 Lanes 16
Standards Given in Ministry of Transport and Civil Aviation Memorandum No 653 (Roads in Rural Areas) 1950
2 Lanes
3 Lanes
Dual 2-Lane
Flow, Thousand Motor Vehicles per 16 Hour Day (August)
(6490A)
"ENGINEERING"

Fig. 1 Estimated distribution of traffic on trunk roads in England and Wales, 1958.

In view of the increasing importance of road transport in the national economy and of the rapid rate of increase of traffic, it is important to ensure that the road transport system is maintained at a high level of economic efficiency. This paper discusses the conditions on the roads today and considers some of the ways in which economic efficiency might be improved.

ROAD CONDITIONS NOW

The Road System.—In Great Britain there are about 190,000 miles of public road, about one-third in urban areas. This mileage is subdivided into various classes of road[3, 4] as shown in Table I.

TABLE I.—*Mileage of Roads in Great Britain (1957–58)*

Class of road	Urban	Rural	Total
Trunk	1,620	6,689	8,309
Class I	6,103	13,603	19,706
Class II	3,812	13,794	17,606
Class III	5,317	43,532	48,849
Unclassified	40,221	56,299	96,520
Total	57,073	133,917	190,990

These classes are important for administrative purposes, but from the engineering point of view variations in width and other physical characteristics are of greater interest. A limited amount of information is available on these matters, based on a sample of 1,000 points distributed at random on the road network. It is estimated that for England and Wales the mileages of roads of various widths are as shown in Table II.

TABLE II.—*Estimated Mileages of Roads of Various Widths in England and Wales*

Effective number of lanes	Carriageway width (ft)	Mileage of road		
		Urban	Rural	Total
1	8—13	2,200	33,400	35,600
2	14—19	16,900	56,200	73,100
2	20—26	25,300	17,800	43,100
3	27—39	6,600	2,200	8,800
4	40 or more (inc. dual carriageway)	900	100	1,000
Total		51,900	109,700	161,600

The sample also suggests that in England and Wales about 4 per cent of the whole mileage is curved with a radius of 500 ft or less and another 7 per cent curved with radii between 500 and 1,500 ft. The average gradient is 1 in 48; 45 per cent of roads have a gradient of less than 1 in 100, and 18 per cent have a gradient of 1 in 20 or more.

Traffic Distribution.—Glanville and Smeed[7] have given estimates of the distribution of traffic on trunk, class I and class II roads in England and Wales in relation to the currently recommended capacity figures of the Ministry of Transport and Civil Aviation[8]; (these standards are now being revised). They showed that in 1957 about 62 per cent of trunk roads, 23 per cent of class I roads and 6 per cent of class II roads carried flows in excess of the design capacity. The total length of road in this category was about 8,000 miles, or about a quarter of the total trunk, class I and class II mileage. If no improvements were made to the road system this mileage would increase at the rate of 700 miles per year owing to increases in traffic, which is growing at the rate of about 7½ per cent per annum.

In the case of trunk roads, similar estimated distribution curves of traffic have been found for two-, three- and four-lane roads, separately, in the year 1958, as shown in Fig. 1. These curves show that of rural trunk roads, in 1958 the proportions exceeding the old Ministry design flow were approximately: two-lane, 65 per cent; three-lane, 70 per cent; and four-lane, 10 per cent.

Traffic Composition.—It is estimated that the total vehicle-mileage in urban and rural areas in Great Britain in 1958 can be broken down into classes of vehicles as shown in Table III.

TABLE III.—*Estimated Composition of Vehicle Mileage, 1958*

—	Vehicle mileage (thousand millions)		
	Urban	Rural	Total
Cars and taxis	19·4	17·4	36·8
Goods vehicles	9·0	6·6	15·6
Public service vehicles ..	1·4	0·8	2·2
Motorcycles	3·1	1·9	5·0
All motor vehicles	32·9	26·7	59·6
Pedal cycles	6·9	2·3	9·2

Paper entitled "Road Traffic Economics" read before a joint meeting of the Engineering and Economics Sections of the British Association at York, September, 1959. (See note at head of page 175.)

Although the flow of pedal cycles is about 15 per cent of that of motor vehicles, the interaction between pedal cycles and other traffic has not been studied in detail; pedal cycles will, therefore, be ignored in the remainder of this paper.

Speeds.—Measurements of speed of travel have been made at a number of places. On high-quality roads average speeds are of the order shown in Table IV.

TABLE IV.—*Average Speeds on Good Rural Roads in Light Traffic*

Type of vehicle	Average speed (m.p.h.)	
	Wide, straight, level, uninterrupted all-purpose roads	Motorway (Preston By pass)
Car	48	53
Light goods	41	45
Medium goods (including bus and coach)	34	36
Heavy goods	30	32
Average (normal composition)	43	48

Many factors, including curvature, gradient, narrowing of the carriageway and the presence of other traffic, tend to reduce speeds.

Each increase of 100° of horizontal curvature per mile of road reduces the average speed of cars by 3·1 m.p.h. and that of goods vehicles by 1·7 m.p.h. Each 100 ft of rise and fall per mile of road reduces the average speed of cars by about 0·9 m.p.h. and that of commercial vehicles, which are more sensitive to gradient, by about 2·2 m.p.h. The effects of traffic flow and road width on the speed of the average vehicle on rural roads are illustrated in Fig. 2. In light traffic the average speed is about 4 m.p.h. lower on a two-lane road than on a three-lane road: with cars the corresponding difference is about 6 m.p.h.

It is estimated that in 1958 on rural roads average journey speeds (including traffic delays but not intentional stops) and vehicle-mileages were as shown in Table V.

TABLE V.—*Journey Speeds and Vehicle-Mileage on Rural Roads*

—	Average journey speed, m.p.h.	Vehicle-mileage (thousand millions)
Trunk	36	10·7
Class I	33	7·5
Class II	31	2·7
Class III	28	4·0
Unclassified	25	1·8
All roads	32	26·7

In urban areas average speeds vary from about 25 m.p.h. on suburban main roads to about 5 m.p.h. in parts of the congested central areas of cities. For instance, on about 7 per cent of roads in Central London and 18 per cent of roads in Central Glasgow, the average speed is less than 6 m.p.h. Typical average speeds in various areas are given in Table VI.

TABLE VI.—*Typical Daytime Journey Speeds in Urban Areas*

—	Average journey speed m.p.h.
Central areas:	
Glasgow	8
Newcastle	9
London	10
Slough	10
Worcester	12
Edinburgh	13
Stafford	14
Stamford	14
Suburban shopping streets	15–18
Radial routes in London	16–26
Built-up areas on a cross-country journey	25

Overall it is estimated that in 1958 on the 53,000 miles of urban roads in England and Wales, 32,900 million vehicle-miles were travelled at an average speed of 20 m.p.h.

Accidents.—There were about 237,000 personal injury accidents in 1958, involving about 300,000 casualties, of which 5,970 were fatal. There were about 216,000 casualties in built-up areas of which 1·6 per cent were fatal and 20 per cent serious; there were about 83,000 casualties in non-built-up areas, of which 2·9 per cent were fatal and 30 per cent serious. A very approximate estimate of the overall injury accident rate for 1958 is as follows:—

Built-up areas, 5½ per million vehicle-miles.
Non-built-up areas, 2 per million vehicle-miles.
All areas, 4 per million vehicle-miles.

A study of injury accidents and traffic flow on 140 miles of two-lane roads and 33 miles of three-lane roads in Buckinghamshire in 1951 and on 80 miles of dual carriageway in England and Wales in 1952 gave the following rates:—

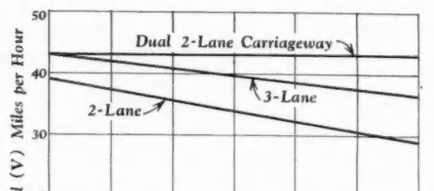
Two-lane, 2·3 per million vehicle-miles.
Three-lane, 2·6 per million vehicle-miles.
Dual carriageway, 1·6 per million vehicle-miles.

The results for three-lane roads are based on a comparatively small sample, but a more comprehensive investigation into accident rates on these roads is in hand.

ROAD TRANSPORT COSTS

As has been seen, conditions on the road at present leave room for improvement. It is, however, necessary to consider to what extent improvements are possible and to what extent such improvements are economically justified. For this reason costs of road transport need to be evaluated, especially as they are affected by possible changes in road and traffic conditions.

Operating and Labour Costs.—Road transport costs are affected by changes in the road system and road conditions through changes in the time or distance required for particular journeys. Perhaps the most direct method of evaluating



(6490 8) "ENGINEERING"

Fig. 2 Speed/flow relationships on straight level roads with "normal" traffic composition (23 per cent medium/heavy vehicles).

full costs is to determine what road users are willing to pay for savings in time and distance. Some limited experimental work in this field has been attempted but the results so far do not appear to have been very fruitful. An alternative approach has therefore been adopted by attempting to evaluate separately the vehicle operating costs, costs of users' time and costs of accidents. Difficulties arise with this method in establishing representative values of some factors and in the value people place on leisure (or non-working) time.

The total cost per vehicle-mile consists of a number of elements, of which some are constant, some vary in proportion to journey time per mile and others (such as fuel costs) vary in a more complicated way as speed or journey time changes. Within limited ranges of speed, it is possible to express all costs per mile approximately in the form of a "basic" cost plus a cost varying in proportion to journey time. Estimates of these costs have been made: all are considered net of taxation and licences (which are a transfer within the community with no real cost involved) and of insurance (because accident costs, which insurance is intended to cover, are considered separately).

The principal costs that may be assumed to vary directly with time are the cost of the working time of vehicle occupants and the overhead costs of commercially-operated vehicles which may be allocated to the working time of the vehicle, e.g. interest on capital invested in the vehicle and costs of cleaning. In research into the effect of road conditions on fuel consumption[9] it was found that, apart from a "basic" element, fuel consumption also tended to change in direct proportion to journey time per mile for speeds below about 40 m.p.h. for private cars and light goods vehicles and below about 30 m.p.h. for medium and heavy goods vehicles. It was assumed that tyre wear and about one-third of the maintenance and depreciation costs attributable to vehicle operation would change in the same way and in the same proportion as fuel consumption. However, for average speeds between about 40 and 50 m.p.h. (light vehicles) and 30 and 40 m.p.h. (others), operating costs per mile tend to change only slightly with journey speed and consequently in these speed ranges the change in operating costs with journey time per mile no longer occurs.

Summing all these costs, costs per vehicle-mile at different speeds for a traffic flow of given composition (65 per cent cars, 5 per cent buses and coaches, 12 per cent light goods vehicles and 18 per cent medium and heavy goods vehicles—the average composition on trunk and class I roads in 1956) may be given as:

$$C_M = 4{\cdot}0 + \frac{100}{V} \quad (V < 35 \text{ m.p.h.})$$

$$C_M = 4{\cdot}6 + \frac{80}{V} \quad (35 > V < 45 \text{ m.p.h.})$$

where C_M is the average total cost per vehicle-mile in pence and V the average journey speed of all motor traffic in m.p.h., i.e. not the speed of an individual vehicle. It should be noted that the relation between cost and speed has a different form at higher speeds. These costs do not apply directly to intersections where the effect of road conditions on traffic is normally expressed in terms of vehicle-hours of delay. The relevant costs of delay per vehicle-hour, however, correspond closely to costs at speeds of less than 35 m.p.h. and will be approximately 100 pence per vehicle-hour.

Total Costs and Congestion.—At the estimated average speeds of 20 m.p.h. and 32 m.p.h. in urban and rural areas respectively, the cost formula above gives the total current cost of road transport as £2,020 million (net of tax) which agrees closely with the independent estimate of about £2,100 million (net of tax) given by the figures in the introductory paragraphs, particularly since the latter estimate includes several items excluded from the former, e.g. insurance and cost of travel by cycle and motorcycle. These data may also be used to estimate the total cost of congestion, which may be defined as the difference between total cost at present estimated speeds and total cost at what might be regarded as reasonable speeds. Assuming the latter to be 25 m.p.h. and 40 m.p.h. in urban and rural areas respectively, the estimate cost of congestion in 1958 is some £200 million, equal to about 10 per cent of total road transport cost on a comparable basis.

Cost of Accidents.—Road accidents are a further cost attributable to road transport but their valuation is a difficult and controversial process because of people's views on the value of human life and suffering. But their attitude and policy on road accidents, however, the community and the Government are already implicitly placing values on human life and suffering, and it seems preferable to make this process more systematic.

Briefly, accidents may be valued by estimating the cost of damage to property, medical expenses, administrative costs and the value of the net loss of output due to injury and death, the loss due to a person's death being the present value of his expected future output less his expected future consumption.[10] Thus it is estimated that the total cost of road accidents measured in this way was £133 million in 1958 and the average total

cost of a personal injury accident was £460, with a wide range; the average cost of a person's death was estimated at some £2,700, of a serious injury at £700 and of a slight injury at £50. The average cost of a non-injury accident was estimated at about £50.

INCREASING ROAD TRANSPORT EFFICIENCY

Price Mechanism.—Road transport does not pay directly and specifically for the roads that it uses (although it does make a substantial contribution to general taxation) and many of its problems and their remedies are connected with this fact. Thus, where road space is scarce in relation to demand and roads are congested, vehicles may be paying less than the full cost of their journeys; the full cost includes that of the congestion which they impose on other vehicles. The use of the price mechanism to charge road users the full cost of their journeys in such circumstances would benefit road users as a whole, since journeys for which road users were unwilling to pay full costs (and for which the full cost must therefore exceed benefits) would be eliminated. The price mechanism is being applied to a limited extent in the case of parking where its application is relatively straightforward but its extension to cover all road use in congested areas would probably encounter serious practical and administrative difficulties. However, it might be appropriate in some seriously congested areas where additional road space is costly to provide and it is being increasingly discussed as a means of securing more efficient utilisation of existing roads.

Road Improvement.—Where roads are congested and dangerous, and road transport costs, including accident costs, could be reduced by road improvement by more than the cost of additional road space (and the same result could not be achieved in any cheaper way) then expansion and improvement of the road system is appropriate. In practice this is at present the main line of attack on the road transport problem and, since annual expenditure on road improvement is expected to reach at least £60 million, it is important to consider the case of road improvement in some detail.

The economic case for a road improvement and its contribution towards a net reduction in total road transport costs (including the cost of the road system) may be assessed in its initial effects by first estimating annual vehicle-mileage carried out by present traffic and average cost per vehicle-mile before and after improvement to give the net change in travel costs, and adding to this the estimated annual change in the cost of accidents. Annual additional maintenance costs are then deducted to give net annual savings which are expressed as a percentage rate of return on the capital cost of the improvement. A rate of return higher than the long-term rate of interest will then indicate that there has been a net reduction in total road transport costs and that the road improvement is apparently justified. This does not necessarily mean, however, that the improvement is fully justified because one cannot always be sure that better alternatives both as to type and scale of improvement do not exist.

The best improvement is that which minimises the total transport costs. The appropriate scale of improvement is given by carrying the improvement to the point at which the rate of return on, for example, the last increment of width is equal to the relevant rate of interest*: the appropriate type of improvement is that giving the highest rate of return if carried to that point. This suggests an economic approach to the design of road improvements and the consideration of alternative road improvements in order to deal with any particular problem. In practice circumstances and realistic (economic) road standards such as those discussed later will dictate the appropriate type and scale of improvement fairly clearly in many cases, although in some cases there may be many feasible alternatives and considerable examination of those alternatives may be necessary, e.g. where there is a real choice between improving existing roads and the construction of new ones.

Returns from Road Improvements.—The calculation of the rate of return for a particular improvement is shown in some detail in Appendix I. Examples of returns from actual and proposed improvements are given in Table VII although these cannot necessarily be taken as being representative of road improvements in general.

TABLE VII.—*Examples of Rates of Return from Some Actual and Proposed Improvements*

Type of improvement	Capital cost of improvement (£ thousand)	Estimated rate of return on completion (per cent)
Widenings: Rural Road ..	167	1½
	638	4*
	1,500	4*
	1,000	6*
Urban street ..	116	13
	280	14
Urban intersection	204	36*
	3·5	51
	5	1,730*
Bypasses	723	0*†
	442	7
	97	10
	450	10
	415	13
	255	14
	210	16
Realignment	25	16*
Bridge	224	11

* Proposed improvement rate of return based on predicted conditions. (See Assessment of Priorities below).
† In this case diversion of through traffic to the bypass would cause a loss.

Of the 18 examples in Table VII, four have rates of return of less than 5 per cent, and five have rates greater than 15 per cent with an unweighted average of 13 per cent (excluding one extreme item). Summing total costs and benefits from all these schemes gives an overall rate of return of about 9 per cent.

Secondary Effects.—So far, in this section, analysis of road improvements has been largely confined to their primary effects, i.e., their effects on present or existing traffic patterns, on the assumption that everything else remains equal. Road improvements may have substantial secondary effects, however, in diverting traffic from unimproved to improved routes or by expanding total traffic volumes either by more journeys being made with the same means of transport or by changes in the means of transport e.g. transfer from public to private transport; these latter phenomena are usually referred to as generated traffic.

Diversion of traffic represents a gain to the traffic diverted and to the traffic on the route from which diversion takes place, but a loss to the traffic on existing routes to which diversion takes place. Generation of traffic represents a gain to the additional traffic but a loss to other traffic on the improved route. It may be seen therefore that the consideration of road improvements will range from a fairly simple process in the case of straightforward improvements, where little or no consideration of alternatives is necessary and where secondary effects may be ignored, to a highly complex process where many alternatives may exist and where secondary effects may be substantial. These secondary effects may occur over a long period of time and are often difficult to measure and to distinguish from other changes such as secular or local traffic trends.

Assessment of Priorities. — Before-and-after studies of road improvements that have already been carried out yield valuable and interesting information, but for the planning of the road system it is essential to evolve methods of prediction so that the benefits from planned improvements may be assessed and priorities decided in order that expenditure shall be concentrated on those that are urgent and beneficial. To do this, and to select from a large number of improvements that have already been planned, techniques of prediction have been evolved. These use known relationships between speed or delay and traffic flow, road width curvature, gradient, the presence of traffic control devices, parked vehicles and other factors, to estimate the effects of a given improvement on traffic. Information on accidents and on accident rates per vehicle-mile also enables the effects on accidents of various kinds of road improvement to be predicted.

To allow for the time required to plan and to carry out the improvement (and to give some weight to future conditions) it is suggested that the effects on traffic and accidents five years hence should be the basis of assessment, although this may mean that the absolute capacities of the unimproved roads may be exceeded and normal relationships break down. In these circumstances it has been decided to impose arbitrary upper or lower limits to delay and speed. The rate of return to be expected from improvement may then be calculated in the same way as given above and, subject to the same qualifications with regard to secondary effects and other complicating factors, rates of return may then be used as indications of priority. However, because prediction is involved and because the effects of many factors cannot be precisely predicted, rates of return arrived at by these methods are more open to error than those obtained from before-and-after studies.

While the above technique is appropriate for discriminating between a set of given road improvements which have been put forward, in the longer run the overall economic planning of the road system will demand the establishment of economic standards, such as are given below, against which present road conditions may be compared. Such a comparison will then identify the points at which improvement appears necessary and should, with considerable further development of standards, indicate the type and scale of improvement required and the time at which the work should be done.

ECONOMIC TRAFFIC CAPACITY OF ROADS

An attempt to establish economic standards on the lines referred to in the previous section has been made in the case of rural roads.

Concept of "Economic Capacity."—Rural roads conventionally have an integral number of lanes, either two, three, four (in dual carriageways) or six (dual), largely on commensense grounds. Consider a typical two-lane road, carrying a steadily increasing volume of traffic. As the volume of traffic increases the average speed will fall, as shown in Fig. 2, and the total cost of travel will therefore increase. But Fig. 2 also shows that this cost could be reduced at any level of flow by widening the road to three lanes. The benefit so obtained can be evaluated and this also increases with increasing flow. This can be compared with the fixed cost of widening from two to three lanes and ultimately a flow will be reached at which the rate of return justified the expenditure of the necessary capital. This level of flow may be called the economic capacity of the two-lane road.

This concept was introduced by Schuhl[11] and independently by Charlesworth,[12] but has not previously been defined precisely. The following definition is proposed:—

> The *economic capacity* of a road is the total traffic passing along it in a year which, with the hourly distribution and composition by vehicle type throughout the year, peculiar to that road, is just not sufficient to make any road widening economically justifiable when the monetary benefits to road users are compared with the overall cost of the improvement, taking the current rate of return on capital investment as a standard.

This definition refers solely to economic benefits. The difficulty of evaluating savings in

* In the long run this may be assumed to be equal to the long term rate of interest which stood at about 5 per cent in early 1959, but in the short run with a back-log of road improvements the relevant rate may be higher.

non-working time and reduction in suffering caused by accidents has been discussed, and in the first instance these factors will be ignored. Also the amount of road widening is not specified. In the case of rural roads, as has been pointed out, widening will normally be one step in the series 2-3-4-6 lanes. It will be assumed in the first instance that the best step is always the next in the series. In the case of urban roads the situation is different since there is not normally the restriction to a small number of alternative road widths.

Economic Capacity for Rural Roads.—As an illustration of the method, the economic capacity of straight and level two and three-lane roads in rural areas will be considered. The relevant speed/flow relations are shown in Fig. 2. From these relations the saving in vehicle-hours in any hour due to widening from two to three lanes, or three lanes to a two-lane dual carriageway, can be calculated. This has to be done for each hour in the year to give the annual savings. A study of the variation in traffic flow throughout the year at two typical points has shown that an appropriate "average" flow can be used for this purpose and, conveniently, this is approximately equal to the average hourly flow in a 16-hour day (6 a.m. to 10 p.m.) in August.

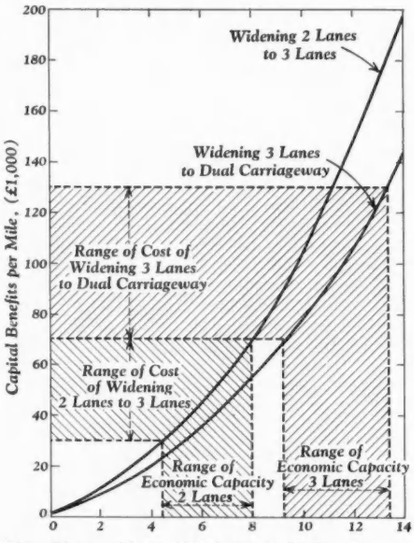

Widening 2 Lanes to 3 Lanes
Widening 3 Lanes to Dual Carriageway
Range of Cost of Widening 3 Lanes to Dual Carriageway
Range of Cost of Widening 2 Lanes to 3 Lanes
Range of Economic Capacity 2 Lanes
Range of Economic Capacity 3 Lanes
Capital Benefits per Mile, (£1,000)
Flow, Thousand Motor Vehicles per 16-Hr Day (August)
(6490.c) "ENGINEERING"

Fig. 3 Relation between capital benefits from widening and flow on straight level rural roads (including the effect of estimated changes in the accident rate).

This is the basis of the censuses carried out periodically by the Ministry of Transport and Civil Aviation at some 5,000 points on main roads in this country, the latest being that for 1954. The savings corresponding to this "average" flow have to be multiplied by a factor (about 6,000) to convert them to annual savings, and costed in the way described earlier.

The total economic benefits from widening will be affected by changes in accident rates. It was shown earlier that on a particular sample of roads the average personal-injury accident rates per million vehicle-miles were: two-lane road, 2·3; three-lane roads, 2·6; and dual carriageways, 1·6. These accident rates have been assumed to apply and a personal-injury accident has been costed as described above. The total resulting benefits of widening from two to three lanes and from three lanes to dual carriageway are shown, in relation to flow, in Fig. 3. They are expressed as a capital sum per mile of road, assuming an interest rate of 5 per cent.

Information on the costs of rural road widening, kindly provided by the Ministry of Transport, has been examined. Rounded off these costs are summarised in Table VIII.

TABLE VIII.—*Costs of Road Widening*

	Cost per mile (£ thousand)	
	Normal range	Average
2 to 3 lanes	30–70	50
2 lanes to dual carriageway (2 × 2 lanes)	60–130	
3 lanes to dual carriageway (2 × 2 lanes)	70–130	100

At first sight it may seem surprising that widening from two lanes to dual carriageway tends to be cheaper than widening from three lanes to dual carriageway. However, in the latter case the third lane is of no direct value to the dual carriageway, which is frequently constructed by building a second carriageway, possibly some distance from the first. The extra lane in the existing carriageway may be left in being, making an unsymmetrical road, or destroyed, thereby adding to the cost of construction. The extra cost is therefore not unexpected.

These costs are also shown in Fig. 3. (Any increase in maintenance costs due to widening has been neglected. Maintenance costs must depend to some extent on the width of the carriageway but they are also dependent on the total traffic and this remains the same.) The horizontal line denoting the cost in Fig. 3 meets the appropriate curve at a flow level equal to the economic capacity. The ranges of economic capacity for straight and level roads corresponding to the ranges of cost are as follows:

Two lanes: 4,500-8,000 motor vehicles per 16-hour day.

Three lanes: 9,000-13,500 motor vehicles per 16-hour day.

It should be emphasised that these figures are tentative and are based only on the limited data at present available. They also make no allowance for the value of non-working time, though few people would regard it as valueless. The inclusion of a value for non-working time—if a value could be arrived at—might reduce economic capacities considerably.

Widening a Two-Lane Road.—So far it has been assumed that a two-lane road will in the course of time, if traffic continues to increase, become first a three-lane road and later a dual carriageway. However, it might be more profitable to omit the three-lane stage altogether. If this alternative is examined, it can be shown that in a typical case the benefits over the period covered by the three-lane road (of the order of 12 years at the present rate of increase of traffic) are about 75 per cent greater for a dual carriageway. The present cost of the two-stage process, on the other hand, would be about the same as that of the single-stage process. It follows that, at least in some instances, the omission of the three-lane road would appear to be justified. The result depends on the changes in accident rate which have been assumed and on the assumption that traffic will continue to increase (although not necessarily at the present rate) until widening from three lanes to dual carriageway would be justified. This means that the one-stage process is the more risky.

CONCLUSIONS

(1) Road transport represents a very important part of the national economy. Expenditure net of tax is currently about one-seventh of the net national income and is rising rapidly. Tax on road users and vehicles is a substantial source of revenue to the Exchequer, amounting to about £500 million per annum at present.

(2) The average speed of traffic is estimated to be about 20 m.p.h. in built-up areas and a little over 30 m.p.h. in rural areas. Increasing traffic flow and consequent increasing congestion are tending to reduce these speeds. In some areas they are already much lower and many miles of roads are inadequate for the traffic they have to carry. Present plans for expenditure by the central Government of some £60 million annually on new works will help to ease traffic flow.

(3) Methods are available for estimating the economic benefits to be expected from road works. Excluding savings in non-working time and relief of human suffering, it is estimated that at present the average rate of return being obtained from road works on completion is probably between 5 and 15 per cent per annum. It is possible that some of these yields would be affected by attraction of traffic from other forms of transport and by new traffic.

(4) At present there is a large back-log of improvements which require to be made and for which plans are ready. It is suggested that the rate of return on these investments should be used to help in the assessment of priorities.

(5) A more comprehensive long-term procedure is required. The use of economic standards of road design, on the lines of those suggested for road width, should help to provide such a procedure, and to minimise road transport costs while satisfying requirements.

Acknowledgment.—This paper is published by permission of the Director of Road Research.

APPENDIX

Example of Calculation of Rate of Return for Widening of Urban Street

A section of city street 0·15 mile long carrying about 8 million vehicles per annum was widened from 40 to 60 ft at a cost of £280,000 with little or no additional maintenance. Average journey speed (including periods when vehicles are stationary) over a longer section of 0·39 mile increased from 8·1 m.p.h. before improvement to 10·1 m.p.h. after improvement, the traffic flow having increased by about 4 per cent in the seven months between the measurements of speed. Without the increase in traffic, which may have been fortuitous, it may be estimated that average journey speed would have increased to about 10·6 m.p.h. and it may be calculated that the resultant savings in vehicle operating costs and labour costs were some £38,000 per annum, a net rate of return of about 14 per cent per annum.

REFERENCES

[1] British Transport Commission, *Transport Statistics, 1958*. British Transport Commission (1959).

[2] British Road Federation, *Basic Road Statistics 1958*. British Road Federation (1958).

[3] Minister of Transport and Civil Aviation, *Roads in England and Wales*, Report 1957-58. HMSO (1958).

[4] Scottish Home Department, *Industry and Employment in Scotland and Scottish Roads Report, 1958*. HMSO (1959).

[5] Hansard, *Parliamentary Debates, House of Commons*, vol. 602, No. 78, p. 228 (1959).

[6] Rudd, E., "Estimates of Expenditure on Road Transport in Great Britain." *J. Roy. Statist. Soc.*, (A) vol. 115, p. 179 (1952).

[7] Glanville, W. H., and Smeed, R. J., "Basic Requirements for the Roads of Great Britain," *Conference on the Highway Needs of Great Britain, 1957*, Inst. C.E. (1958).

[8] Ministry of Transport and Civil Aviation, "The Design of Roads in Rural Areas." MTCA circular letter to highway authorities, No. 727 (1956).

[9] Roth, G. J., "The Economic Benefits to be Obtained by Road Improvements, with Special Reference to Vehicle Operating Costs." *Road Research Laboratory Research Note* No. RN/3426/GJR (Unpublished).

[10] Reynolds, D. J., "The Cost of Road Accidents." *J. Roy. Statist. Soc.*, (A), vol. 119, p. 393 (1956).

[11] Schuhl, A., "Design Width of Roads in Relation to Traffic." *La Route*, No. 166 (bis), p. 33 (1948).

[12] Charlesworth, G., "Research on Town Traffic." *Final Report, Public Works and Municipal Services Congress*, 1952, p. 468 (1953).

British Association Meeting

PROMISING FUTURE OF VERTICAL TAKE-OFF

By H. G. CONWAY, M.A., M.I.Mech.E., F.R.Ae.S.

Director and Chief Engineer, Short Brothers and Harland Limited

A research aircraft has been built by Mr. Conway's company to explore the range of flight from hovering to conventional forward flight. It has four jet engines for lifting and one for propulsion. Landing and take-off are automatically controlled. This British aircraft is working and is perhaps nearer to practical operation than corresponding approaches in other countries. Such an aircraft could reduce substantially the size and cost of world airports.

THE progress in the sphere of aeronautics over the last 50 years has been nothing short of fantastic and the recent extensions into astronautics indicate that the rate of progress in the next 50 years is likely to be even more incredible. Probably no other sphere, not excepting nuclear physics, has seen such developments. Many examples can be found in supersonic flight, long range transport at relatively low cost across the North Atlantic (which has only been in operation for some ten years), jet propulsion with engines giving thrusts in excess of 25,000 lb and engines which give 8 or more pounds of thrust for every pound of dead weight.

Now interest has been awakened in vertical-take-off and landing aircraft, or VTOL as it is called. Most of these developments have been made possible by the corresponding developments in automatic control, since the human operator or pilot is generally incapable of controlling the equipment under the difficult conditions or environment which these developments dictate.

There are many ways of achieving VTOL or STOL (short take-off and landing). The helicopter is the most obvious example, but this paper is not concerned with discussing solutions of this type, involving the downward thrust of propellors or fans on relatively large masses of air moving at low velocity. It will deal with jet-lift solutions of the type which Rolls-Royce and the author's company, Short Brothers and Harland, have been working on in recent years, as these would appear to offer the only prospect of combining conventional flight at high speed with the ability to hover and to land or take-off vertically.

The whole field of known possibilities has been surveyed excellently by others elsewhere, and the present objective is to illustrate some of the engineering problems and possibilities that the particular solution with which the author is familiar may lead to.

The main issue itself is a fairly simple one—if we can place sufficient reliance on a multiplicity of lifting engines and electro-mechanical stabilising systems the dividends in the military field and to the ordinary air-travelling public are potentially enormous.

WHY VTO?

There are several main reasons for the recent interest in VTO—some obvious, others more obscure. It is clear, for example, that almost everyone, except perhaps the civil engineering contractor, is dismayed by the large section of urban areas which have to be laid out as airports. The typical dimension of a modern runway is 3,000 yd long, 100 yd wide (300,000 sq. yd) and at least 12 in thick (i.e. 100,000 cu. yd of concrete). A large airport will have two parallel runways in each of three directions and this together with the taxiways and aprons means that a typical airport could have the best part of one million cu. yd of concrete. This is a lot of concrete. The ability to take-off and land vertically will enable the operating area of an airport to be reduced to a few hundred square yards.

Because of the multiplicity of landing directions on a conventional airport (6 to 12) the area of urban disturbance around the airfield is substantial. It is for this reason that on many modern airports certain jet transport aircraft are only permitted to land at certain times in the day or in certain directions. The relative areas of disturbance of the conventional airfield and the VTO landing field are greatly different, as Fig. 1 shows; although the actual noise level below the jet axis of the VTO aircraft may be worse than for a conventional jet aircraft, the area of disturbance is much less.

In the military case, the tactical freedom which VTO gives must be of considerable consequence to the user and will enable an air force to contemplate operating in mountains or in a remote field far away from an aerodrome. The same argument can be applied to carrier-borne strike aircraft—it seems reasonable to suppose that the obvious vulnerability of the large aircraft carrier could be overcome by the use of one or two VTO aircraft operating from a small area at the rear of a small naval vessel, small enough to risk operating close to the enemy, and capable of taking on the aircraft without having to steam into wind. Such novel and non-traditional solutions are more acceptable to the aircraft engineer than to the naval constructor—the former dismisses the objections to lack of hangar space by suggesting collapsable or inflatable coverings on deck, and by accepting the challenge to design equipment proof against sea water.

These arguments are obviously tremendously important, though perhaps less so in global war strategy than in the "minor peripheral disturbances" that we hear so much of nowadays.

Another reason for VTO is a more complex one. Suppose it were possible to evolve an aerodynamic configuration which would be suitable for high speed flight but which could not be made to fly sufficiently slowly to permit conventional landing or take-off at speeds below say 150 m.p.h. The introduction of VTO as a means of getting the aircraft into the air and back on to the ground might be justified notwithstanding the fact that it represented so much dead weight during 95 per cent of the flying time of the aircraft. Dr. A. A. Griffith of Rolls-Royce has been the chief exponent of this philosophy, and has produced some very interesting design studies showing aircraft of narrow delta configuration capable of flying at high speed and long range and yet incapable of leaving the ground without a special VTO engine system.

These reasons have been behind the Ministry of Supply sponsoring the work at both Rolls-Royce and Shorts. There is however another reason for VTO, more subtle than the others. If the regular air traveller were asked what development he looks forward to next, he would probably ask for regularity of operation rather than supersonic flight or increased safety. Speed is desirable mainly because few air travellers are in the air for pure pleasure and the objective is to reach the desired destination; reliability can always be improved but it is now adequate enough not to deter an increasing number of travellers to take to the air each year. But anyone who travels frequently will know how frustrating delays and the uncertainty of operation can be in winter, particularly in Europe and parts of North America. The development of all-weather or blind landing systems will overcome this.

The excellent work of the Blind Landing Establishment at Bedford has shown that conventional instrument landing systems can be extended to operate fully automatically; but is it reasonable to rely on the intersection of an ILS glide path of $1\frac{1}{4}°$ to 2° inclination with a runway as the proper method for an aircraft which may be approaching at 120 to 150 m.p.h.? The degree of geometrical precision with the whole process is excessive, to say nothing of the physical dangers of low terrain clearance on the approach over urban areas.

The answer may lie in VTOL. Here the approach path can be relatively steep with a final let-down in a vertical direction under con-

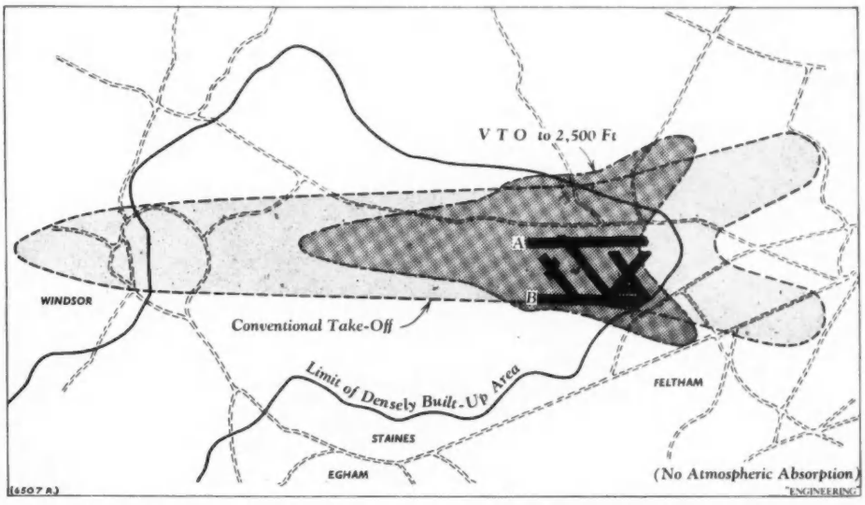


Fig. 1 The relative areas of disturbance of conventional and VTO aircraft for a single take-off direction at London Airport. In practice at least two and possibly six directions are used. (Diagram Crown Copyright Reserved; reproduced by permission of the Controller, HMSO.)

Paper entitled "VTOL—An Aeronautical Challenge" read before the Engineering Section of the British Association at York, September, 1959. (See note at head of page 175.)

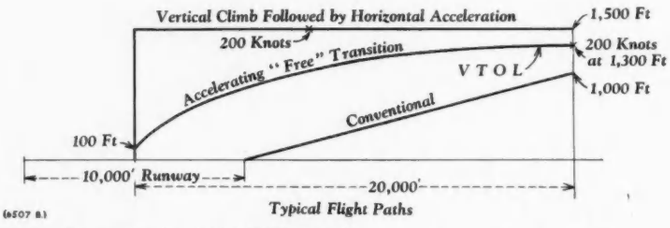


Fig. 2 Conventional and VTOL flight paths (above) and blind landing techniques (right).

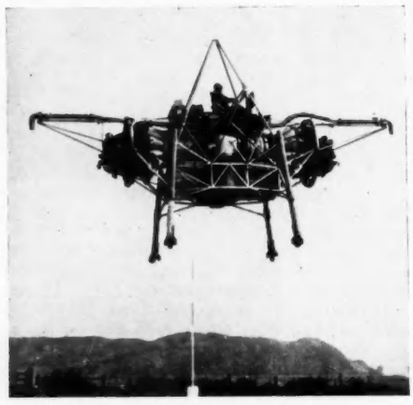


Fig. 3 The Rolls-Royce Flying Bedstead.

Fig. 4 The SC1 aircraft.

trolled conditions. The conventional and the VTO methods are both shown in Fig. 2, which underlines the advantage of the VTO method. The development of the new technique may in fact be the *only* long term answer to all-weather operation.

THE SC 1 AIRCRAFT

The Rolls-Royce "Flying Bedstead"—Fig. 3—proved the principle of jet lift and the basic method of stabilisation by air jets. This consisted of two Nene jet engines mounted in a framework on top of which the pilot sat. Control nozzles were situated on outrigger arms and by bleeding-off some of the compressor air and feeding it to these pipes, the pilot or an autostabiliser was able to control the attitude of the aircraft during hovering.

The next step has been to construct a research aircraft (the SC 1) which makes use of similar principles but is designed to explore the range of flight between hovering and conventional forward flying and to carry out transitions from one mode to the other. The aircraft is shown in Fig. 4.

The principle of the stabilisation system will become more apparent from the diagram shown in the Fig. 5. There are four small lifting engines (Rolls-Royce RB 108) which produce enough thrust to lift the aircraft off the ground. There is a fifth engine for propulsion in the rear of the aircraft. Air bleed from the compressors of the four engines feeds nozzles at the front and rear and on the wing tips of the aircraft. Control valves are fitted to these nozzles to enable the pilot to control the flow of air and thus the thrust from the nozzles by moving his conventional stick. As the diagram shows, when he is hovering he can give himself stability by moving these nozzles. In forward flight he uses the conventional control surfaces as shown on the diagram.

A simple sum will show the dead weight penalty, and how much fuel can be used in lifting an aircraft off the ground or allowing it to land again vertically. The average jet engine has a fuel consumption of 1 lb per lb of thrust per hour. Let the assumed weight of the aircraft be 100 units and that of the vertical thrust (to allow for acceleration and engine failure) 120 units. The installed weight of the lifting engines, which may themselves weigh less than 1/9 lb per lb of thrust, can be (say) 1/6 lb weight per lb of thrust. Thus the installed engine weight is 20 units (out of the 100 units of aircraft weight). The fuel required for a total hovering time of 5 minutes is a further 10 units of weight making the total VTO weight 30 per cent of the aircraft weight. Obviously very substantial advantages must be gained from the system before such a weight penalty becomes practicable and in fact the above figures can be bettered. Notwithstanding these penalties there are many people who feel that this type of VTO is here to stay.

ENGINEERING A JET-LIFT VTOL

The engine itself is the major problem but is outside the scope of the present article. The RB 108 engine is most effective and its high response rate (due to the small diameter of the rotor assembly) has been found to give highly desirable hovering characteristics. The time constant of thrust increase as the throttle is opened is relatively very low.

In discussing briefly some of the other engineering problems the assumption is made that the practicability of the whole system has been proved. This is certainly so to the engineers working on the aircraft, but is scarcely acceptable yet to the unbiased scientist

Most of the aerodynamic problems on the aircraft are conventional, though the problem of momentum drag is much more severe than on normal aircraft. As shown in Fig. 6, the loss of momentum of the incoming air at the engine intake causes a severe nose-up pitching moment. The air mass is then accelerated to the efflux jet velocity to create the lifting thrust. Although the thrust is proportional to the mass times jet velocity the momentum drag for a given intake speed is proportional to the mass. The lowest value of momentum drag will thus be caused by the highest efflux jet velocity; if the problem of overcoming the momentum drag is substantial on a jet-lift aircraft of the SC 1 type it will be even worse on aircraft of the ducted fan type where the efflux velocity is lower.

The present solution is to tilt the lifting engines backwards so that some part of the lifting thrust can be used for forward acceleration to overcome the momentum drag during a transition. The whole problem of engine installation, intake design and means of swivelling the direction of the jet efflux is complicated and one on which much research work remains to be done. It is obviously very much associated with a particular aircraft configuration. Development of this nature has been much hampered by the fact that jet-lift engines are not easy to install in slave aircraft for test purposes; until such time as VTO aircraft are available in substantial numbers

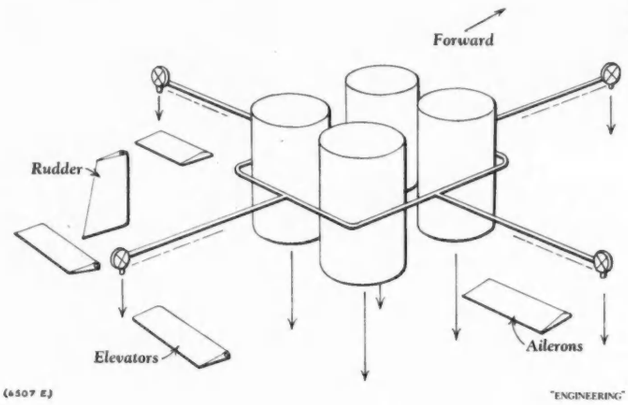


Fig. 5 (left) The SC1 stabilisation system.

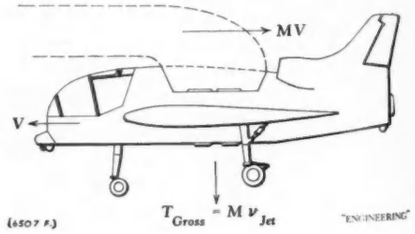


Fig. 6 (right) Momentum drag.

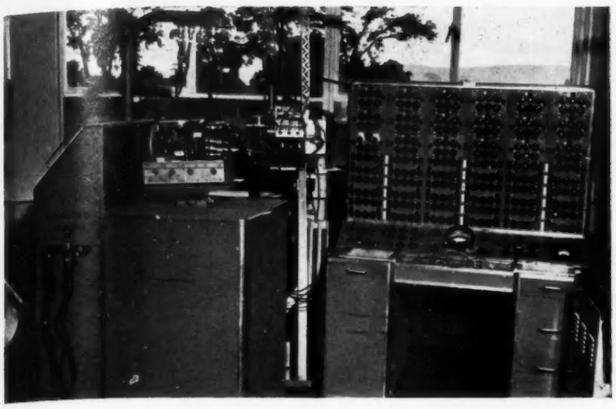


Fig. 7 (above) Gyro rocking table and computer set-up.

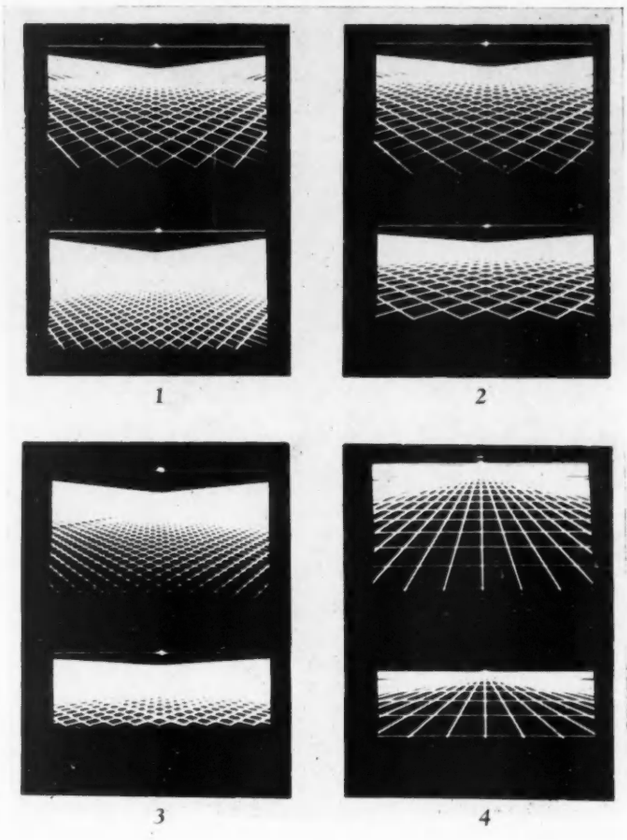


Fig. 8 (right) Diagram from experimental optical flight analogue.

engine development must of necessity be relatively slow.

STABILISATION PROBLEMS

Most modern aircraft will be fitted with an autopilot, but conventional autopilot equipment will be unsuitable for stabilising an aircraft during hovering. It has been and indeed will continue to be argued that the pilot should be able to stabilise the aircraft during the relatively short time of hovering required for the vertical take-off and landing, relying on the conventional type of autopilot for normal flight. The engineering opinion of the author and his colleagues is that even if a skilled pilot could learn to stabilise the aircraft under favourable conditions, or perhaps with the use of a simple gyro or accelerometer-based damper system, it is unreasonable to expect him to do so, particularly during an instrument landing when he has many other things to do. For this reason the whole of the work at Belfast is based on the use of automatic stabilisation or, to be more precise, on the premise that full automatic control will be necessary in any civil VTO application and for the successful accomplishment of most military missions.

The modern autopilot is of relatively limited "authority," meaning that should a runaway occur, the pilot must be able to regain control and prevent a dangerous incident. A typical runaway rate would give say 5° of aircraft pitch in the first second. Model test-rig work has however shown that to control a VTO aircraft during hovering requires a control system of such power that an angular acceleration of about 0·5 to 1·0 radian per sec per sec can be achieved, i.e. 30° to 60° in the first second.

What is not yet certain however is how best to apply this control power. On the one hand it is known that it is too much to expect the pilot to do the whole stabilisation, and on the other hand the fully automatic system, as on the SC 1, may be too complicated for some applications. A mixture of pilot and stabiliser (i.e. a pilot-aid) may be a good answer but not enough is yet known of the relative ratios or authorities. The full stabilisation system of the SC 1 is several times more powerful than the conventional autopilot and involves time lags so short that no pilot could catch a runaway. This has led to the use of duplicated systems in the Bedstead, triplicated systems on the SC 1 and will probably lead to quadruplicated systems later.

The question of safety of this type of system has been much discussed in recent years both from the point of view of practical engineering and from a philosophical standpoint. It can be said with some assurance that a duplicated system would require a fault detection system which would be more complicated than the third channel to achieve the necessary degree of safety. This led to the adoption in 1954 of a three-channel system on the SC 1, so arranged that whatever happens to one channel there is always at least one good channel which can operate the aircraft safely—assuming that the worst case requires the neutralisation of a faulty channel by means of the second channel. It is normal aircraft practice not to deal with a double-fault case; aircraft with power controls, for example, only have the controls duplicated and should one fail the aircraft is expected to land on the remaining system. The risks with an autostabilisation system are rather greater however and it may be that for civil use a quadruplicated system will be required to give protection even against a second fault, but this may not necessarily mean greater complication.

SIMULATION TESTING

The analogue computer, less well known than the digital type, is now an essential tool of any engineer concerned with the design of aircraft, missiles or servo systems—in fact any dynamic system where the equations of motion can be set up as electrical analogues, and integrated or otherwise processed so that the result of a given disturbance applied to the system can be viewed on a cathode ray tube, or pen recorder.

The development of analogue computers has enabled a new type of flight simulation technique to be developed. Instead of just simulating the performance of an aircraft when it receives a disturbance by viewing a cathode ray tube, it is possible with an analogue computer (and not practicable with a digital type) to replace parts of the simulated system with real equipment. Thus a cockpit with a blind-flying panel can be coupled to a computer system representing the aerodynamic performance of the aircraft. When the pilot moves his control column the response which he sees on the dials is representative of the performance on the corresponding real aeroplane. This assumes of course that the computer has been correctly set up, but mathematical knowledge of the performance of aircraft is sufficiently good to enable this to be done realistically.

In the case of the SC1, simulation was originally resorted to because there was no other means of tackling flight and stability problems until the aircraft had been built. In the early days there were doubts about correlations with reality but these have been eliminated with experience.

Thus the pilot is able to "blind-fly" the aircraft for many hours before he takes the real machine in the air. Many firms have now found that this is invaluable in the design of a

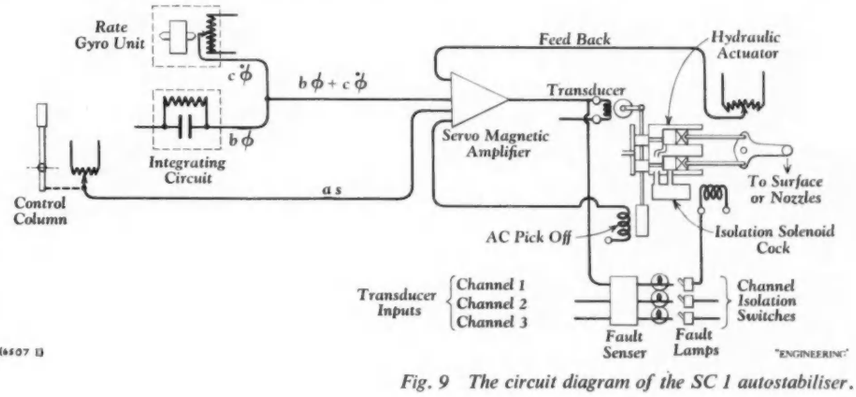


Fig. 9 The circuit diagram of the SC 1 autostabiliser.

Fig. 10 Rate gyro.

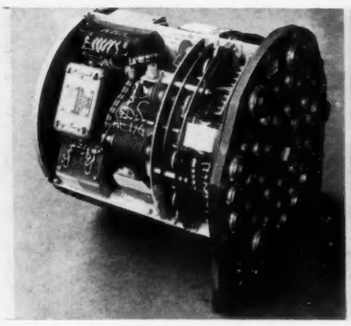


Fig. 11 Gyro control unit.

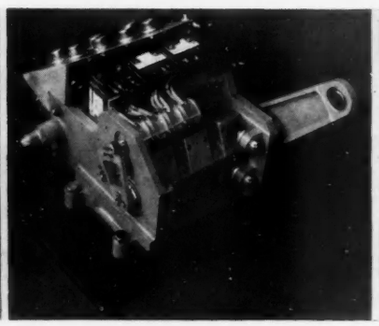


Fig. 12 Electro-hydraulic servo motor.

Fig. 13 Valve element motor.

new aircraft and enables adequate confirmation of the likely performance of the aircraft to be obtained before the prototype leaves the ground.

The development of an autopilot system using gyroscopes requires some means of tilting the gyroscopes if representative motions or rates are to be applied. As conventional rocking tables merely apply continuous, sinusoidal motions to the gyros, a two-axis servo table has been developed to allow the gyro control units to be rocked at representative rates (say up to 30° per sec) in response to stepped inputs as demanded by the motion of a joystick or pilot's control column. Fig. 7 illustrates the table coupled to a computer and carrying a gyro unit. Use of a two-axis table means omitting yaw signals if pitch and roll are introduced, but this has been found acceptable. A three-axis table is very much more complicated and expensive and has not been considered to be worthwhile.

The next step in this development programme is to replace the blind flying panel with something representing the normal visual panorama which the pilot sees so that he is not relying on blind flying experience.

One approach to this technique is to give the pilot a projected CRT display with an optical analogue of the horizon ground pattern or of the approach lights seen at night. Fig. 8 illustrates an experimental grid of this type. The other is to project a wide angle picture similar in effect to Cinerama, coupled to the pilot's stick so that the picture moves about five or even six axes in response to the pilot's demands.

An experimental simulator has been built on this technique. The optical system is interesting in that it uses a point source of light (the point being approximately 1·5 mm in diameter) projecting through a transparent three-dimensional lantern slide, representing the ground, on to a curved screen. Instead of the pilot actually moving himself he causes movement of the light with respect to the model thus projecting a realistic picture of the moving ground on his screen; if the source of light is kept close to the pilot's eye the optical and physiological realism is extraordinarily good.

This particular work has not proceeded due to lack of MOS interest, though research work is in hand in the United States. It has been said that pure visual simulation divorced from physical effects due to acceleration can be most misleading to a pilot trained to correlate, at least subsonsciously, eye and " seat-of-the-pants." On the experimental machine it was not difficult to become sick due purely to visual effects and the criticism is probably valid as the whole problem is highly complex. Provided the optical motion rates are limited (as in normal flight) there is no doubt in the author's mind that some form of visual cueing is essential to the proper interpretation of flight simulator presentations.

CONTROL ENGINEERING

Reference has already been made to the problem of safety in relation to autostabilisers of high authority. This has lead to the use of a three-channel autostabiliser system so arranged

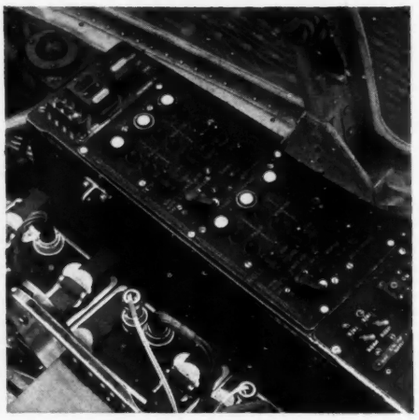


Fig. 14 Pilot's control panel.

that any failure on one channel still leaves at least one channel operative.

The principle of the autostabiliser system used is best illustrated by its equation:

Control displacement $= as + b\theta + c\dot{\theta}$

where a = pilot's stick displacement

θ = angle in pitch or bank of aircraft

a, b, c = constants.

This will be seen to be a mixture of an attitude term to provide stabilisation in a given axis (as determined by the gyro axis) and rate of change of attitude to provide damping during motion. A later development of the system goes further and adds in an " integral-of-error " term to eliminate permanent error or drift for reasons connected with aircraft trimming.

The practical realisation of a system to give a required control equation could use a free gyro to produce the attitude signal and a rate gyro to produce rate terms. In practice the scheme used at present is based on work done at the Royal Aircraft Establishment, and uses a single rate gyro per channel, the output from which is integrated by a condenser to produce an attitude term; the circuit is shown in Fig. 9. Because the rate gyro drifts and has an imperfect zero, a resistance is introduced across the integrating condenser to allow a continuous signal leak, thus limiting the memory of the system to a small (but adequate) number of seconds.

The engineering interest of this system may be seen in the following illustrations:

Fig. 10—The rate gyro; note the fine pick-off on which the whole channel performance depends.
Fig. 11—The gyro control unit, with magnetic amplifier and tantalum capacitor pack.
Fig. 12—The electro-hydraulic servo motor.
Fig. 13—The valve element of the servo motor.
Fig. 14—The pilots control panel with indicator lights and switches, so arranged on this research aircraft to allow the pilot to switch out terms in the control equation for research purposes.

A few of the other engineering problems are :

Landing Gear.—This gear has castering wheels on all legs; the main wheels can be moved back for vertical landing to position the centre of gravity sufficiently forwards to allow landing with backward drift. A new type of shock absorber has had to be devised which extends almost without friction so that the pilot can lift the aircraft off the ground level and avoid the tendency to move sideways which would occur if one or more legs tended to stick.

Nozzles.—Various nozzles for use at the ends of the 6 in ducting have been developed. Low operating torque, high efficiency, i.e. low flow losses, and good strength-weight ratio at the operating temperature involved (about 250° C) are requirements.

Ducting.—In light alloy or titanium, with expansion joints, and welded by the latest techniques.

Engine Tilting.—Servo system to allow engines to be swivelled fore and aft, and able to deal with gyroscopic loadings.

Elevator Power Controls—This aerodynamic control surface has been introduced so that when climbing or descending vertically the unbalanced forces on the elevator do not react back to the pilot.

THE FUTURE

The final question is: when will VTO of the type represented by the SC1 and the Rolls-Royce RB108 power plant go into service? The answer given can only be a personal opinion. A small military strike aircraft based on the SC1 formula could be operational by 1965/66. More ambitious solutions of supersonic transports involve the parallel development of supersonic techniques, themselves troublesome; no doubt 1970 is the earliest date in this case.

Much depends on government policy for aeronautical research and the rate of development that can be afforded. Typical costs of modern large transport aircraft are £15 to £16 per lb of empty weight of the whole aircraft, which breaks down into about £12 per lb for the airframe and £20 to £24 per lb for the power plant. Whereas the conventional aircraft has engines giving 30 per cent of the aircraft weight in thrust, the VTO aircraft has about four times this number. It seems probable therefore that a VTO transport will cost £20 per lb or more, giving a first cost of two to three million pounds for a typical North Atlantic aircraft.

Jet lift of the type described is a British development which is justifying a substantial expenditure by the Ministry of Supply. Credit for many original ideas lies with engineers at the Royal Aircraft Establishment; Rolls-Royce have produced for it a power plant with perhaps the most remarkable performance of any jet power plant so far developed.

The author's firm, awarded the contract for the development of a suitable airframe and its control system as a result of a design competition, has maintained enthusiasm and belief in VTO in spite of " White Papers on Defence," financial crisis and scepticism. The results now being achieved show that this British solution will work and is perhaps nearer to being applied operationally than solutions seen in other countries.